Georgia Water System Audits and Water Loss Control Manual

Produced for:

Georgia Department of Natural Resources

Georgia Environmental Protection Division
Georgia Watershed Protection Branch

March – 2016
Version 2.0

Georgia Water System Audits and Water Loss Control Manual – Version 2.0

Revised March 2016

The 4th Edition (Version 2.0) of the *Georgia Water System Audits and Water Loss Control Manual* was prepared by the Georgia Association of Water Professionals (GAWP). It was written through the dedicated work of a standing subcommittee under the Georgia Water Loss Control Committee (GWLCC). GWLCC members of this subcommittee include:

Dan Carter, Subcommittee Chair
Eco-Tech Inc.

David Kubala
Cherokee County Water and Sewerage Authority

Lebone Moeti, Ph.D.
Georgia Environmental Protection Division

Will Jernigan, P.E., GWLCC Chair
Cavanaugh

Kathy Nguyen
Cobb County Water System

Brian Skeens, P.E.
CH2M

Ed Urheim
GRWA

Jason Jay
Columbus Water Works

Summary of Version 2.0 Manual Updates

Section 3 – Water Audit Data Grading and Validation: This is an entirely new addition to this manual. The content for Section 3 was developed as a function of the Qualified Water Loss Auditor program implemented in early 2016, including background on data validation, and the 10-step Level 1 Validation method required by EPD for certification of water audits beginning with those submitted in March 2016.

Section 4 – Planning a Water Loss Control Program: This section has been updated to provide additional narrative on the Water Loss Control Program and demonstration of progress.

Contents

SECTION 1–The Importance of Water Loss Auditing and Control

1.1 Background and Regulatory Drivers

Georgia is home to 2,400 public water systems, of which 1,700 are community water systems. Within our state there are more than 70,000 miles of rivers and streams, numerous ponds and lakes, and one of the most productive aquifers in the world. Georgia receives, on average, about 50 inches of rainfall annually. Yet, demands on Georgia's water resources are growing. Federal, state and local management decisions are increasingly scrutinized due to conflicts over use of shared resources. The cost of providing reliable drinking water in Georgia is also increasing due to factors such as aging infrastructure, increased energy costs, and more complex and costly changes to the requirements for safe drinking water. And even though Georgia has abundant water resources, the water resources are neither evenly distributed across the state nor does the rain that replenishes those water resources fall in equal amounts across the state in any given time period. These factors, along with population growth in Georgia, may cause some regions of the state to experience water demands that exceed locally available supply.

Georgia has embarked on several comprehensive water management strategies to meet these challenges. The ratification of Georgia's first Statewide Water Management Plan in 2008, the development of regional water management plans (2003 – 2011), and the passage of landmark water stewardship legislation (2010), signify a shift in water management that affects every facet of our water environment. Of particular importance is the need to create and support a culture of conservation throughout the state by improving how efficiently water is used.

Water system inefficiencies increase the cost of service to customers and may lead to increased raw water demands that negatively impact the natural environment. Water system audits and water loss control are valuable water management strategies that can improve the efficiency of water production and delivery in water systems of all sizes within the state.

This document, the Georgia Water System Audits and Water Loss Control Manual, serves as a "guidance manual" and describes the current best practices necessary to complete a water system audit and implement a water loss control program in Georgia. The standards for conducting audits are in accordance with the International Water Association (IWA) / American

Water Works Association (AWWA) methodology for water loss auditing, and reports are submitted to the Georgia Environmental Protection Division (EPD) on an annual basis by the affected water providers.

1.2 Rules for Public Water Systems to Improve Water Supply Efficiency

In June 2015, the Board of the Department of Natural Resources (DNR) adopted 'Rules for Public Water Systems to Improve Water Supply Efficiency', Chapter 391-3-33. The purpose of these rules was to establish policies, procedures, requirements and standards as included in the Georgia Water Stewardship Act (GWSA) of 2010 (sometimes referred to as SB 370). This Act is a multifaceted approach to water conservation and it requires specific action by water providers serving 3,300 or more in population. Approximately 250 water providers in Georgia, who provide 80 percent of the potable water to the state's population, are affected by this Act (as of 2011). Specific to public water systems, Section 3 of the GWSA amends O.C.G.A. Sec. 12-5-4 and requires the following of water providers:

- Water systems serving a population of "at least 3,300" must conduct an **annual water system audit**.
- Water systems serving a population of "at least 3,300" must implement a **water loss control program**.
- EPD requires public water systems to conduct standardized annual water loss audits according to the IWA/AWWA methodology and requires that water systems submit those audits to EPD in a timely fashion.

Special Note: EPD uses an allocation factor of 2.6 "persons per connection" when determining "population served" from the number of metered connections in a residential water system.

1.3 Georgia EPD Reporting Process

The GWSA requires water systems to conduct water audits according to the IWA/AWWA methods, following best practices adopted by EPD. The *Georgia Water System Audits and Water Loss Control Manual* was developed around similar themes as the AWWA *Free Water Audit Software© (version 5.0 or later),* and provides supplemental assistance for water providers to utilize this software. This software is the required methodology for performing an acceptable water audit in Georgia and it follows the required IWA/AWWA standard as dictated by the

GWSA.

- For public water systems serving at least **3,300 individuals (or population served), the GWSA requires annual water audits covering the previous calendar year to be submitted to EPD no later than March 1st of the following calendar year**.

Special Note: The GWSA requires EPD to post all submitted audits on its website. Therefore, **electronic** submissions will be **required** from all affected water systems. Annual water audits must be submitted electronically to Water.Audits@dnr.ga.gov. If a system has special circumsta**nces that** makes it impossible t**o submit** an annual audit by March 1st, contact EPD by email (same as above) or by telephone (404-463-1511) for additional guidance.

Documents to be submitted to EPD include:

- The water audit file in Microsoft Excel format, with all worksheets completed, including the Basis of Audit documentation in the Comments Tab or attached in comparable format. .

Special Note*:* In the future, water withdrawal permits, water plant operations permit controlled production increases, and Drinking Water State Revolving Fund loans through the Georgia Environmental Finance Authority (GEFA) may take into consideration water audit results and the development and implementation of water loss control programs.

Special Note: Updated information and technical resources on the Water System Audit and Loss Control Program are available online under the Water Loss Auditing section of GAWP's website – www.gawp.org – and on EPD's website – https://epd.georgia.gov/water-loss-audit-results. Programmatic updates to include the most up-to-date version of the *Georgia Water System Audits and Water Loss Control Manual*, state regulations and rule-making processes/schedules, and additional water auditing resources can be found here.

SECTION 2–Conducting a Water Audit

Real Losses are the annual volumes lost through all types of leaks and breaks in water mains and service connections, up to the point of customer metering. Real losses also include overflows from treated water storage tanks or reservoirs.

Apparent Losses occur due to errors generated while collecting and storing customer usage data. The three categories of apparent losses include: Unauthorized Consumption, Customer Metering Inaccuracies, and Systematic Data Handling Errors.

2.1 General Notes

The updates to the Georgia Water System Audits and Water Loss Control Manual are based on using the best management practices to complete a water audit and take into account lessons learned from the water audits conducted to date. The Metropolitan North Georgia Water Planning District convened a group of water providers in 2010 and developed an excellent guidance document to assist utilities in completing the Reporting Worksheet of the software, which has been closely referenced in the updating of this manual.

Trying to achieve a water loss of zero isn't practical or expected. Understanding that water losses are broken down into two categories – real losses and apparent losses – is important as the data collection is started and then input into the water audit spreadsheet. Additional sample calculations have been included in this manual to assist in developing inputs into the audit spreadsheet.

The primary goal of reducing real losses is represented by the infrastructure leakage index (ILI) and the normalized real loss performance indicators of gallons/service connection/day or gallons/mile/day. The water audit software calculates these performance indicators. Apparent losses must be quantified as accurately as possible in order to have greater confidence in the quantity of real losses.

It should be noted that it requires several years of conducting water audits to provide more accurate data for audit inputs. This requires bottom-up activities and field studies that supplement the desk-top data entered into the audit spreadsheet. As the data validity improves over the years, ILI values and other performance indicators should not be viewed as definitive, but rather should be viewed in combination with the data integrity score over time. It is always critical to remember that the goal is to improve the validity score over time so that there is an improved understanding of both real and apparent losses. It would not be unusual for the ILI values to increase as system leakages are more reliably quantified with improved data.

The need to maintain complete and accurate documentation used in conducting water audits is critical, not only because they may be subject to EPD audit, but also because this documentation provides the basis of calculations for the water audit and will be used by future new personnel who will eventually become involved in the audit process. A folder with a Microsoft Excel or Word file showing where the data originated and how the calculations were performed should be accessible to a number of personnel to maintain continuity in subsequent years.

Water audits are required to be conducted over the 12-month calendar year. While water systems may have different fiscal operating years, based on the experience of the first two years of water audits, the best approach for the calendar year reporting cycle is the internal use of rolling 12-month audits. These audits are based on tracking data on a month-to-month basis, and become part of the standard operating procedure in managing the water system. This forces various personnel involved in collecting and reporting the data to be more familiar with what is expected and not overwhelmed when the time comes to submit the annual audit. This also allows changes in data trends to be tracked throughout the year and analyzed for any anomalies.

2.2 Required Methodology for Water Audits

AWWA Free Water Audit Software© (version 5.0 or later)

The current version of the AWWA Free Water Audit Software© is version 5.0, released in 2014. Version 5.0 has several enhanced features and functionality, including:

- *Inputs & Outputs separated into 2 tabs*
- *Meter error adjustment for all water supplied components*
- *Clarifications and enhancements to grading matrix*
- *Clarifications and enhancements to definitions*
- *New Water Loss Dashboard for visual display of non-revenue water components*
- *New comments page for capture of essential supporting information*

Version 5.0 will be the required format beginning with the 2015 audit submittal (by March 1st, 2016).

Special Note: It is EPD policy to use this software for **all** water systems affected by the GWSA requirements. The AWWA *Free Water Audit Software*© is not intended to provide a full and detailed water audit. For guidance on comprehensive auditing procedures, see AWWA's M36 publication *Water Audits and Loss Control Programs*. The software does allow water utilities to quickly compile a preliminary audit in a standardized and transparent manner advocated by EPD. To download the **AWWA *Free Water Audit Software*©** visit the AWWA website (see Reference section on last page of this document). Please note that you will need to register/login (no cost) to the AWWA website before downloading the software.

Please note the software is in Microsoft Excel format.

The AWWA *Free Water Audit Software*© includes multiple worksheets in a spreadsheet file. The first worksheet provides instructions on the use of the software. *It is essential to complete the administrative inputs on the instructions tab, including but not limited to the utility's PWS ID# and the units of reporting (typically Million Gallons).* The majority of data is entered on the second worksheet, the *Reporting Worksheet*, which prompts the user to enter standard water supply information such as the volume of water supplied, customer consumption, distribution system attributes, and quantities of losses.

It is understood that many water utilities do not typically tabulate all of this data, therefore, some of the values may be easier to determine than others. All data entry cells should be completed. If the input value is known and verified, its data grading should be higher; if the input value is estimated, its data grading should be lower. Some input cells provide a default value and default data grading that can be used until more accurate data is acquired. In addition, the software calculates a variety of performance indicators that are very useful in quantifying system performance. Refer to Section 2.8 in this manual for further discussion on the derivation and interpretation of audit results.

2.3 Reporting Worksheet - WATER SUPPLIED

The "water supplied" section quantifies the total volume of treated water that is pumped into the distribution system.

Volume from Own Sources (VFOS)

This is the amount of water leaving the water treatment plant recorded by the production master meter(s). This number can be obtained from monthly operating reports submitted to EPD.

- List the treated water sources to ensure none are overlooked. Groundwater that directly enters the distribution system should be added. Groundwater that is treated at a water treatment plant will be counted by the production meter.

- The “master meter” in this section refers only to the finished water meters measuring flow input into the distribution system, and does not refer to any large customer meters that may casually be referred to as master meters.

VFOS Master Meter and Supply Error Adjustment

The adjustments made to the production master meter(s) recorded volumes based on meter flow verification that accounts for errors in measurement, calibration, data gaps from communication interruptions or other data archival issues.

Special Note: Because no water meter is 100 percent accurate 100 percent of the time, a value for this input - however minimal - should be entered in this cell. Zero is not a realistic input.

Special Note: An important distinction should be drawn between ‘flow verification’ and ‘calibration’. Flow verification is the act of confirming the accuracy of the primary metering device – the measuring element. Flow verification requires an independent measurement, typically by a second meter in series with the first, to provide comparative readings. Comparative readings are what provide us with the ability to quantify the error.

Calibration is the act of making modifications to the secondary electronic device – the output device where the flowmeter’s measured values are converted and communicated. Typically this can be a differential pressure transducer or cell that converts the flowmeter measurement into a common electronic signal (i.e., 4-20 mA) used in the telemetry or SCADA system.

Be careful not to confuse these two terms, or to assume they are the same. Flow verification is for the primary metering device, calibration is for the secondary electronic device, and both are vital in providing the highest degree of confidence in the water supplied volume, which is the most important input in the water audit.

- Production master meters should be flow verified and calibrated annually at a minimum, per EPD requirements. Flow verification and calibration records should document the existing meter reading, as well as the adjustment made to the meter to calculate the over/under calibration difference as a percentage. Adjustments to the production master meter based on the flow verification report are entered in this field following *Example 1*.
- If the meter is flow verified and calibrated more frequently (i.e., quarterly), calculate a flow-weighted average following *Example 2*.
- If there are multiple production master meters operating in parallel, provide an average weighted by flow volume to determine the total master meter and supply error adjustment.

- ***Special Note:*** It is unlikely that a utility will enter a grading value of 10 in column E and enter an error adjustment of zero. Even with very good data, a meter adjustment is likely; therefore a volume associated with this adjustment should be entered. While storing flow verification and calibration data as a new tab in a companion workbook is always recommended, keeping a copy of the independent meter flow verification and calibration results is strongly recommended.

Example 1 - Meter flow verified annually:

Flow Verification Date	Test Meter Accuracy	Subject Meter Accuracy	Percent Error	Water Produced in Year	Annual Master Meter and Supply Error Adjustment
Jan-1-09	100%	98.5%	-1.5%	100 million	-1.50 million
Total Master Meter and Supply Error Adjustment(-0.015) x (100 million)=					-1.50 million

- Note: For this example, select “under-register” from the drop-down box because the meter under-registered the volume by 1.5 million gallons.

Example 2 – Meter flow verified quarterly:

Flow Verification Date	Test Meter Accuracy	Subject Meter Accuracy	Percent Error	Water Produced in Quarter	Quarterly Master Meter and Supply Error Adjustment
Jan-1-09	100%	98.5%	-1.5%	20 million	- 0.3 million
Apr-1-09	100%	99.0%	-1.0%	30 million	- 0.3 million
Jul-1-09	100%	99.0%	-1.0%	40 million	- 0.4 million
Oct-1-09	100%	101.5%	+1.5%	10 million	0.15 million
Total Master Meter and Supply Error Adjustment (sum of 4 numbers) =					-0.85 million

- Note: For this example, using software version 5.0 or newer (required), enter this input (cell N15) as a negative number since it represents under-registration.

Water Imported (WI)

This is the water purchased from a neighboring utility or regional water authority.

- Meters that measure this volume should be verified by the seller and thus be reflected in the bill received from the seller. The purchaser (the Utility completing the water audit) should request documentation to verify the accuracy of these meters regularly.

WI Master Meter and Supply Error Adjustment

The adjustments made to the import meter(s) recorded volumes are based on meter flow verification that accounts for errors in measurement, calibration, data gaps from communicating interruptions or other data archival issues. *Using software version 5.0 or newer (required), enter this input as a positive value or percent for over-registration, and a negative value or percent for under-registration.*

Water Exported (WE)

This is the water sold to a neighboring utility or regional water authority.

- Adjustments to water export meters should be reflected in the water bill sent to the customer and included in the “water exported” number.

- Water export meters should be tested (flow verified and calibrated, depending on the meter type) regularly. For large water exporters (20% or more of produced water is exported), the testing interval should be consistent with production master meter testing. For smaller water exporters, meters measuring exported water should be tested at least once every 3 years.

WE Master Meter and Supply Error Adjustment

The adjustments made to the export meter(s) recorded volumes based on meter flow verification that accounts for errors in measurement, calibration, data gaps from communicating interruptions or other data archival issues. *Using software version 5.0 or newer (required), enter this input as a positive value or percent for over-registration, and a negative value or percent for under-registration.*

2.4 Reporting Worksheet - AUTHORIZED CONSUMPTION

Authorized consumption refers to the volume of water that is used by an authorized customer. This category does not include water sold to other utilities, which is considered water exported in Section 2.3. The general categories with basic descriptions of authorized consumption are listed below. More specific sources of data within each category are provided in **Table 5 (Section 4.2)**. The sources listed in **Table 5** are not exhaustive, and are provided only as a guide for potential sources of data.

Billed Metered

This category includes water that is metered and billed for domestic, commercial, industrial or institutional customers.

- It is recommended that water providers periodically check meter readings on inactive accounts to identify billed metered usage that would not be identified during normal meter reading routes because the meter is considered inactive.

Special Note: This number does not include wholesale water sent to neighboring water systems; these wholesale customers are entered in the “Water Exported” section of the Reporting Worksheet (See Section 2.3).

Special Note: Use care when considering estimated bills. Estimated bills and bill adjustments during the same time period are considered billed metered if there is a meter. If estimated consumption is reduced based on better available data, these negative adjustments are considered an Apparent Loss.

Billed Unmetered

This category includes water that is not metered, but is billed and may include customers who are not metered but are charged a fixed fee or other method, or customers with estimated usage.

- For long term or permanent unmetered customers, installing a permanent meter is recommended to obtain actual consumption.

Unbilled Metered

This category includes water that is metered but not billed, such as water provided free of charge for municipal purposes (unbilled public facilities, unbilled public irrigation, etc.).

Unbilled Unmetered

This category includes unmetered water that is unbilled for authorized uses such as firefighting, flushing of mains or sewers, street cleaning, etc.

- Utilities may select the default number of 1.25 percent of the Volume from Own Sources unless they can compile accurate data to justify a different number. Supporting data should be saved in a companion workbook.

- It is recommended that water providers focus on billed metered and billed unmetered data before focusing on unbilled unmetered as it is typically a small percentage of use.

- It is recommended that water providers install meters on all permanent structures regardless of whether it is billed or unbilled to improve data quality.

2.5 Reporting Worksheet - WATER LOSSES

Apparent losses account for errors generated while collecting customer consumption data. The three categories of apparent losses include Unauthorized Consumption, Customer Metering Inaccuracies, and Systematic Data Handling Errors. The following Section provides descriptions of each type of loss and methods of measuring these losses. Real Losses are calculated by the software. More specific sources of data within each category are provided in **Table 6 (Section 4.3)**. The sources listed in **Table 6** are not exhaustive, and are provided only as a guide for potential sources of data.

Unauthorized Consumption

This category includes theft of water such as illegal connections, unauthorized use of fire hydrants, meter tampering, and any other type of water theft.

- Water providers should use the default number of 0.25 percent of the Volume from Own Sources provided in the software unless they can compile accurate water theft data. Supporting data should be saved in a companion workbook.

Customer Metering Inaccuracies

These are inaccuracies that result from wear, improper sizing or maintenance of meters. The value is input as a positive percentage, between 1 percent and 10 percent into the audit.

- If a utility has a meter testing program in place, the accuracy test results for small and large meters should be utilized to calculate this value as a total weighted average, based on consumption (*see Example 3 calculation below*).
- To perform this total weighted average calculation, meter test results for low, mid and high flow ranges must be combined into a single weighted average based on volume, for small and large meters, respectively. The most accurate method to determine the

weighting for the three flow ranges is to flow log a sample of meter accounts. In lieu of this flow logging, AWWA guidelines suggest weighting as follows – 15 percent for low flow, 70 percent mid flow and 15 percent high flow ranges. See *Example 3 calculation* below for further guidance on using these weightings to reach a weighted average for meter test results.

- If a utility does not yet have a meter testing program in place, judgment must be used to estimate the inaccuracy of large and small meters, based on known condition, age and cumulative usage of the meter population.
- AWWA publishes two guidance manuals that can be referenced for sizing water service lines and sizing of meters, as well as maintaining an accurate customer meter population. Refer to *Sizing Water Service Lines and Meters* (M22) and *Water Meters – Selection, Installation, Testing and Maintenance* (M6) for specific guidance.
- For more detailed guidance on this topic, refer to the AWWA *M36 Manual*.

Example 3 – Customer Metering Inaccuracies Calculation

Total water sold in Audit year = 600,000,000 gal
Total water sold through small meters (up to 2”) = 350,000,000 gal (58.30% of total)
Total water sold through large meters (>2”) = 250,000,000 gal (41.70% of total)

	Low Flow Range	Mid Flow Range	High Flow Range
Small meter test results:	87.00%	99.00%	98.00%
Large meter test results:	90.00%	97.00%	101.00%

1. Find the weighted average for small and large test results, respectively:

Small = 87.00%x15.00% + 99.00%x70.00% + 98.00%x15% = 97.05%
Large = 90.00%x15.00% + 97.00%x70.00% + 101.00%x15% = 96.55%

2. Find the weighted average between the small and large meter weighted averages, based on volume of water sold:

97.05%x58.30% + 96.55%x41.70% = 96.84%.

In this example, the total weighted _accuracy_ of the customer meters (large and small, combined) is 96.84%. Therefore, the _inaccuracy_ of the customer meters would be:

100.0 % - 96.84% = 3.16%. Thus, “3.16” is what should be input into the audit for Customer Metering Inaccuracies for this example.

Systematic Data Handling Error

These are errors occurring between the meter readings and billing systems.

- Errors include billing system entry errors, account adjustments, skewed estimates, poor accounting, etc.

- Automatic Meter Reading (AMR) systems can reduce systematic data handling errors compared to manual meter reading systems.
- It is recognized that this value is difficult to quantify. Unless you have conducted a detailed analysis on your billing system database for this purpose, it is recommended to utilize the following default value:
  - *0.25 percent of the Billed Metered volume*
- For more detailed guidance on this topic, refer to the AWWA *M36 Manual*.

2.6 Reporting Worksheet - SYSTEM DATA

The System Data portion of the worksheet describes the physical characteristics of the distribution system. Components are broken down as follows:

Length of Mains

This is the total length of transmission and distribution pipelines in the system; enter this value in units of miles.

Special Note: Length of mains input should not include service lines.

Number of Active and Inactive Service Connections

These include all physical connections to the main, not just the number of accounts in the system because one account could have multiple connections.

Average Length of Customer Service Line

This number should be zero for all water utilities unless a utility's meters are located beyond the customer property line. In Georgia, most or all utilities will use an input value of zero with a data grading of 10. *Using software version 5.0 or newer (required), select "Yes" to the question "Are customer meters typically located at the curbstop or property line?" This will result in the auto-population of the correct input and grade for this entry*. A diagram with corresponding description is provided in the software on the tab "Service Connection Diagram".

Average Operating Pressure

The average system operating pressure is a very important parameter in calculating the unavoidable annual real losses (UARL). All systems are unique and the pressure will vary based on the extent of the system, the elevation changes, the demand patterns, and other local considerations. To limit the variability in pressure measurements that might skew the water audit results, the following standards for pressure measurements are recommended.

- Tank Elevations – It is recommended that the tanks be at the midpoint of normal daily operations. For example if the tanks fluctuate between 60 percent full and 100 percent full, then the measurement should be at 80 percent full. If the tanks operate between zero percent full and 100 percent full, then 50 percent full represents the midpoint.

- Time of Day – Midday is recommended because tanks are typically filled at night, when pressure will be the highest. In the morning, the demand is the highest so the pressure will be the lowest. Midday (noon) is a more representative time for pressure in most systems.

- There are several basic methods for calculating average operating pressure.

  - For water systems with a distribution model, an average pressure can be easily calculated by averaging the pressure at each node in the model. Systems should calibrate the model with field pressure data to verify model accuracy.

  - For water systems with a single pressure zone, a representative sample of static pressure readings across the zone should be taken and averaged. See *Example 4 calculation* below.

  - For water systems with multiple pressure zones, a representative sample of static pressure readings across each zone should be taken, and then the averages for all zones should be combined into a total weighted average, based on miles of main per zone. See *Example 5 calculation* below.

- For more detailed guidance on this topic, refer to the AWWA *M36 Manual*.

Example 4 – Single Pressure Zone Calculation
12 readings taken, measured in psi: 55, 50, 72, 41, 47, 45, 51, 45, 50, 90, 84 and 66.
Average Operating Pressure = (55+50+72+41+47+45+51+45+50+90+84+66) / 12 = 58 psi.

Example 5 – Multi-Pressure Zone Calculation
A system has 3 pressure zones – A, B and C. Total miles of main in the system = 210 miles.
Zone data is as follows:

Zone	Average Zone Pressure (psi)*	Miles of Main	Weighted % of Total Miles of Main
A	76	102	= 102/210 = 48.6%
B	61	32	= 32/210 = 15.2%
C	92	76	= 76/210 = 36.2%

*calculated using the method presented in *Example 4* – Single Pressure Zone Calculation

Average Operating Pressure = (76psi x 48.6%) + (61psi x 15.2%) + (92psi x 36.2%) = 79.5 psi.

2.7 Reporting Worksheet - COST DATA

Total Annual Cost of Operating Water System

These costs should include all the costs for operating just the water system, as stated in its definition in the software.

- If applicable, include costs of shared equipment, debt service payments, and wholesale water purchases.
- Document where the cost figures come from, and any calculations or assumptions made in deriving the figures.
- Where possible, account for the specific water system costs. If it is a combined water and sewer system budget, use a reasonable basis for splitting out the water portion of the costs. See *Example 6 calculation* below.

Special Note: Costs to operate wastewater or other non-potable water operations should not be included.

Example 6 – Annual Operating Cost Calculation

A system has a combined water and sewer operating budget of $2,230,000. There is one water plant and one wastewater plant. The number of water customers is approximately equal to the number of sewer customers. In this example, it would be reasonable to allocate 50 percent of the operating budget to water.

Total Annual Operating Cost = $2,230,000 x 50% = $1,115,000.

Customer Retail Unit Cost

As stated in the definition, this is the charge that customers pay for water service and is applied to apparent losses.

- Be sure to apply the correct units that match the billing units; for example, if water volumes are in million gallons (MG), the cost should be presented in $/1,000 gallons ($/Kgal).

- With tiered water rates, a weighted average is recommended. The weighted-average may simply be calculated by dividing the total year-end billings from retail, volumetric water sales by the total gallons sold. See *Example 7 calculation*.

<u>*Example 7 – Customer Retail Unit Cost Weighted Average Calculation*</u>

Billed Metered (Annual Figure): 15,752 MGY * 1,000 Kgal/MG= 15,752,000 Kgal
Billings from Water Sales (Annual Figure): $63,638,080
Customer Retail Unit Cost = $63,638,080 / (15,752,000 Kgal) = $4.04/Kgal

Special Note: Both M36 and the *Free Water Audit Software*© definitions make reference to including additional charges for sewer, stormwater, or biosolids residuals processing if these are based on water consumption. However, for consistency among all Georgia utilities regarding reporting to EPD, it is recommended not to include these additional charges. Advanced methods for calculating customer retail unit cost are described in M36 and should be considered when evaluating apparent loss reduction and control programs.

Variable Production Cost

This is the current unit cost to treat and distribute water to the system. This cost is calculated per million gallons of water produced or purchased.

Include the variable costs from the audit year associated with production of water (including distribution pumping costs) and wholesale water purchases. Divide the total cost by the volume of water produced.

Other variable costs that go up based on amount of water produced or purchased (residuals treatment and disposal, wear and tear of pumping equipment, etc.) should also be included, if known and applicable. Advanced methods for calculating variable production cost are described in M36 and should be considered when evaluating real loss reduction and control programs. See *Example 8 calculation.*

Example 8 – Variable Production Cost Calculation

Total Variable Costs Divided by Water

Water Supplied: 1,321 MGY

Energy Costs for pumping and treatment (electric, natural gas, diesel, etc.): $575,000

Chemical Costs (treatment at WTP and in distribution system, if applicable): $354,500

Cost of Water Imported: $120,456

Variable Production Cost = ($575,000 + $354,500 + $120,456) / 1,321 MGY = 794.82 $/MG.

Special Note: *Software version 5.0 or newer (required) includes an optional check box on the reporting worksheet beside the Variable Production Cost input, which allows the auditor to use the Customer Retail Unit Cost to value real losses. This may be appropriate in circumstances of constrained water resources with water restrictions in effect, where the reduction of real losses could result in the sale of like volumes of water to customers, thereby allowing new development to occur without increasing water withdrawals. The default setting for this check box is "unchecked", with real loss valued at the Variable Production Cost.*

2.8 Interpreting Software Results

Based on the data entered and the validity scores given to each data entry, the software calculates the values of the performance indicators for the utility. Of these outputs, five parameters stand out in importance: 1) infrastructure leakage index (ILI), 2) data validity score, 3) priority areas for attention, 4) operational basic real losses and 5) operational basic apparent losses.

- **Data Validity Score** is a rating of a utility's confidence and accuracy of data entered into the software on a scale from zero to 100 (all of the 18 data inputs on the Reporting Worksheet are graded 1 to 10, and a composite data validity score [maximum of 100] is calculated by the software). A lower score means the data is less reliable and the utility should focus on improving its data inputs so the software can accurately assess the system water losses. A utility just starting the water audit process and data collection will more than likely have a low data validity score. As a utility's data collection improves, the water audit data validity score should also improve. A "good" data validity score is one that is considered *reflective*, be it high, low or in-between. Refer to the Loss Control

Planning worksheet of the software in order to interpret the Data Validity Score and obtain guidance on the best actions moving forward relative to the use of the data.

- **Infrastructure Leakage Index** (ILI) is the ratio of current annual real losses (CARL) to unavoidable annual real losses (UARL). For most utilities the ILI can be an effective performance indicator for operational management of real losses. When the data validity score is high and the audit is *validated*, an ILI close to "1" indicates the utility's real losses are close to the unavoidable annual real loss level and therefore further reductions in real water losses might not be cost effective. A utility's ILI will fluctuate annually depending on the data collection for each year and therefore should be considered in conjunction with a utility's data validity score and ILI from previous years.

- **Priority Areas for Attention** are listed in order of "suggested" importance with the first being the area identified by the software that the utility should focus on to improve the water audit data and results for the next year. These priority areas are determined based on the data grading entered in the reporting spreadsheet. The utility should focus on improving data collection in the suggested three priority areas. By addressing one or more of these areas, the utility's data validity score and the validity of the performance indicators – including the ILI – will improve. For example, if the first priority area listed was billed metered, the utility would focus on improving the percent of customers with volume-based meters installed; in turn, the utility's data confidence for this input would increase, thus improving the overall data validity score and the validity of the calculated ILI value. Addressing these priority areas will help the utility use resources effectively to improve its water audit results. These priorities **do not** represent areas that need to be addressed to reduce any particular loss.

- ***Operational Basic Apparent Losses (Op23)*** is a basic performance indicator that assesses Apparent Losses in gal/service connection/day. Normalizing the apparent losses calculated through the water audit provides the water utility with a mechanism to monitor these losses as system conditions change and as water loss control measures are implemented.

- ***Operational Basic Real Losses (Op24)*:** is a basic performance indicator that assesses Real Losses in gal/service connection/day or gal/miles of main/day depending on the utility's connection density. This indicator is useful for target setting, and has limited use for comparisons between systems.

2.9 Improving Data Validity

Data Validity is the most critical aspect of the Water Audit and Water Loss Control Program. All reasonable and economically feasible efforts should be made to improve the accuracy of the water audit data. The AWWA *Free Water Audit Software* has a Data Grading Matrix that highlights the specific next steps that can be undertaken to improve the data validity in each of the 18 input areas. Developing *a* water loss control program utilizing an audit with a low validity score, for example below 50, can result in a costly and ineffective program. Under *Priority Areas for Attention* the audit provides three utility specific areas for improvement. These should be reviewed and considered first when improving data validity. A utility will eventually reach a data validity score, where further improvement will be more extensive and significantly more costly while resulting in only incremental improvement. Analysis should be done to determine if these more extensive efforts would result in an audit that would significantly improve system benchmarking and the development of water loss control program.

SECTION 3 – Water Audit Data Grading and Validation

3.1 The Data Validation Process

Water Audits compiled by drinking water utilities are most useful when the data input into the audit reliably reflects the reality of utility operations and performance. To assess the validity, or trustworthiness, of the audit data, each data input into the WAS is graded on a scale of 1-10, with lower validity inputs given a low grading and higher validity inputs assigned a higher grading. Criteria for grading is given in the Grading Matrix worksheet of the WAS (see excerpt in Figure 1).

Water utilities compile the annual water audit by gathering data generated from utility operations (information systems, reports, staff accounts) and placing them in the proper component of the WAS. The auditor assigns the data grading by comparing the characteristics of the data sources and utility practices with those listed in the Grading Matrix worksheet, to select the most representative grading.

Quality of Data in Water Audits

Particularly for water utilities that are new to the water audit process, some of this *self-reported* data may not have a high degree of accuracy, and some of the data gradings may not be representative of the utility practices that generated the data inputs. A knowledgeable third party evaluation of such data is essential to correct less representative data. Even for those utilities experienced in the water audit process, such a validation assessment has proven highly useful.

Data validation is a quality control process conducted to verify – and improve as needed – the data inputs and gradings of the water audits submitted by water utilities. It includes reviews that should be employed once the utility water auditor has submitted the self-reported water audit to the appropriate authority. Data validation should be conducted by a party skilled in the procedures of the data validation process. This is typically a third party to the relationship of the water utility and the appropriate authority. However, the water audit may be validated by a member of the utility – possibly the auditor – if that person is trained as a qualified water auditor in the data validation procedures.

The Data Validation Process includes five levels of data quality which are listed below and defined in Table 1:

- self-reported
- filtered
- level 1 validated
- level 2 validated
- level 3 validated

Self-reported audits have not been subject to any in-depth review. The utility auditor has assigned a data validity grade to each data input based on his or her understanding of the reliability of the contributing data sources and the data validity assignment guidelines presented in WAS.

Filtered audits have been checked for technical plausibility by employing a screening criteria. Beyond a check on whether or not the audit presents a realistic scenario, the accuracy of contributing data sources has not been investigated. Water audits that have implausible results (such as calculating negative losses) should be returned to the water auditor for further review and correction of data inputs that are not reasonable.

Validated audits: Unlike self-reporting and filtering, data validation conducts in-depth review of the data sources and practices of the water utility. Validation can be performed at up to three levels depending on available time and resources, and the level of sophistication needed for the use of the water audit results. Table 1 provides a description of the data validation process with explanations of the three validation levels. Further description of the data quality levels follows in the next section.

Table 1 Water Audit Data Validation Levels

Water Audit Data Validation Levels*					
Level	**Description**	**Validation Focus**	**Typical Activities**	**Level of Effort**	**Effort Depends on:**
	Self-reported	None	None	None	N/A
	Filtered	High level screening	Compare audit results to screening criteria	Small	Defined screening criteria
1	Top down data review validation	Data grades, data validity score, gross errors and anomalies in the metrics	Desktop review of what is immediately available – supply reports, consumption reports, testing reports, etc. Compiler listing of multiple years of water audit data for the utility. One to two hour phone call to interview utility staff, plus preparatory and documentation time. Interview questions are focused on practices to make sure the data grades have been applied correctly and consistently. Via this discussion, anomalies are discussed and either confirmed, corrected, or need for further investigation noted.	Small	System size & complexity, accuracy and completeness of available reports and documentation
2	Top down data mining validation	Supply and consumption volumes from existing data that is mined, at the component and sub-component levels	Data mining for desktop analysis of non-revenue water components. Analysis of available data, including production database and reports from SCADA system to identify gaps in the data chain. Data mining in the billing system to confirm and cleanse consumption volumes to remove redundancies from the data mining process which can come about from record duplications. Also validates exclusion of non-potable volumes in the totals. Validates that consumption volumes from low mid and high level detail extractions are corroborated. Analysis of available meter testing data for audit calculations. May apply 95% confidence limits to the AWWA water balance.	Medium	Complexity of supply setup, metering setup and billing setup. Analysis could be limited to only one or two of the three primary assessments: water supplied volume, customer metering, and billing records.
3	Bottom up field investigation validation	Supply and consumption volumes from new data that is field gathered or mined	Field investigations and extensive data mining. Supply meter testing and in-field verification of meter-transmitter-SCADA data chain. In field customer meter testing. Night flow measurement & analysis to discern leakage flowrates. Pressure and leakage data collection & analysis.	Large	Varies widely by system, largely on how much field work is deemed necessary to assist NRW reduction goals.

*Working Document of AWWA Water Loss Control Committee, Software Subcommittee, Will Jernigan, P.E., Chair and project report *Water Audits in the United States: A Review of Water Losses and Data Validity*, Water Research Foundation Project 4372b (2015)

Data Grading and the Grading Matrix of the AWWA Free Water Audit Software

All numeric inputs of the water audit are input into the AWWA WAS using the Reporting worksheet of the WAS. This includes the volumes of water supplied, billed consumption and apparent losses, as well as system attribute and cost data. Water utilities arrive at the value of these data inputs in a variety of ways. For most water audit components the utility auditor uses a measured or estimated volume. For certain components, the WAS gives the option for the auditor to select a default value that can be used in lieu of otherwise using a crude utility estimate. The default provides a reasonable value that is based upon typical average values found in large water audit datasets, and is graded at the mid-level value of 5. Once the auditor has entered all numeric inputs and assigned a grading to each of the inputs, the WAS calculates a Data Validity Score (DVS) for the utility water audit.

The structure employed in the data grading and use of a DVS provide insight to the water audit in two ways:

1. By providing a quantitative measure of the validity, or trustworthiness, of the individual data inputs
2. By giving insight into the extent that best practices are applied in the utility's operations for each component (data gradings), and for the system as a whole (DVS).

The latter of the above statements reflects the process-based nature of the criteria used to assign gradings to the various data inputs. The criteria is included in the Grading Matrix worksheet of the WAS. Figure 1 gives the first (of eight) pages that exist in the Grading Matrix, and this page includes the components of Volume from Own Sources, Volume from Own Sources Master Meter and Supply Error Adjustment, and Water Imported volume. As can be seen for Volume from Own Sources, the criteria corresponding to a particular grading reflects increasing rigor in the operations and procedures of the water utility as one moves up (left-to-right) on the Grading Matrix. If most of the water sources are unmetered and little meter accuracy testing occurs on existing meters, a low grading of 4 or less is warranted. In progressing up the scale, water utilities must operate current model flowmeters at all water sources, conduct regular flowmeter accuracy tests, and apply the results of the testing to help quantify the Volume from Own Sources Master Meter and Supply Error Adjustment in order to obtain a higher grading of 8 or higher. In order to justify grading this volume at the high level of 10, the utility must conduct flowmeter accuracy testing on a semi-annual basis with findings that less than 10% of the tests produce accuracy results outside of the limits of +/- 3% accuracy. This is a very robust level of flowmeter management. However, the criteria of the Grading Matrix is designed to objectively represent the best practices that water utilities should conduct to manage their water supply at a high level of performance.

In addition to the guidance provided to grade the input volumes, the Grading Matrix also provides – for each component – guidance on the means to improve practices and procedures to qualify for the next highest grading. This gives the utility valuable information on the means to improve both their processes, and the validity of their water audit data inputs.

The auditor will find grading criteria – and improvement guidance – for each of the numeric inputs that are included on the Reporting worksheet of the WAS.

Figure 1 Grading Matrix (Page 1) of the AWWA Free Water Audit Software, Version 5.0

AWWA Free Water Audit Software: Grading Matrix

WAS 5.0

The grading assigned to each audit component and the corresponding recommended improvements and actions are highlighted in yellow. Audit accuracy is likely to be improved by prioritizing those items shown in red

Grading >>>	n/a	1	2	3	4	5	6	7	8	9	10
WATER SUPPLIED											
Volume from own sources:	Select this grading only if the water utility purchases/imports all of its water resources (i.e. has no sources of its own)	Less than 25% of water production sources are metered, remaining sources are estimated. No regular meter accuracy testing or electronic calibration conducted.	25% - 50% of treated water production sources are metered; other sources estimated. No regular meter accuracy testing or electronic calibration conducted.	Conditions between 2 and 4	50% - 75% of treated water production sources are metered, other sources estimated. Occasional meter accuracy testing or electronic calibration conducted.	Conditions between 4 and 6	At least 75% of treated water production sources are metered, or at least 90% of the source flow is derived from metered sources. Meter accuracy testing and/or electronic calibration of related instrumentation is conducted annually. Less than 25% of tested meters are found outside of +/- 6% accuracy.	Conditions between 6 and 8	100% of treated water production sources are metered, meter accuracy testing and electronic calibration of related instrumentation is conducted annually, less than 10% of meters are found outside of +/- 6% accuracy	Conditions between 8 and 10	100% of treated water production sources are metered, meter accuracy testing and electronic calibration of related instrumentation is conducted semi-annually, with less than 10% found outside of +/- 3% accuracy. Procedures are reviewed by a third party knowledgeable in the M36 methodology.
Improvements to attain higher data grading for "Volume from own Sources" component:		to qualify for 2: Organize and launch efforts to collect data for determining volume from own sources	to qualify for 4: Locate all water production sources on maps and in the field, launch meter accuracy testing for existing meters, begin to install meters on unmetered water production sources and replace any obsolete/defective meters.		to qualify for 6: Formalize annual meter accuracy testing for all source meters; specify the frequency of testing. Complete installation of meters on unmetered water production sources and complete replacement of all obsolete/defective meters.		to qualify for 8: Conduct annual meter accuracy testing and calibration of related instrumentation on all meter installations on a regular basis. Complete project to install new, or replace defective existing, meters so that entire production meter population is metered. Repair or replace meters outside of +/- 6% accuracy.		to qualify for 10: Maintain annual meter accuracy testing and calibration of related instrumentation for all meter installations. Repair or replace meters outside of +/- 3% accuracy. Investigate new meter technology; pilot one or more replacements with innovative meters in attempt to further improve meter accuracy.		to maintain 10: Standardize meter accuracy test frequency to semi-annual, or more frequent, for all meters. Repair or replace meters outside of +/- 3% accuracy. Continually investigate/pilot improving metering technology.
Volume from own sources master meter and supply error adjustment:	Select n/a only if the water utility fails to have meters on its sources of supply	Inventory information on meters and paper records of measured volumes exist but are incomplete and/or in a very crude condition; data error cannot be determined	No automatic datalogging of production volumes; daily readings are scribed on paper records without any accountability controls. Flows are not balanced across the water distribution system: tank/storage elevation changes are not employed in calculating the "Volume from own sources" component and archived flow data is adjusted only when grossly evident data error occurs.	Conditions between 2 and 4	Production meter data is logged automatically in electronic format and reviewed at least on a monthly basis with necessary corrections implemented. "Volume from own sources" tabulations include estimate of daily changes in tanks/storage facilities. Meter data is adjusted when gross data errors occur, or occasional meter testing deems this necessary.	Conditions between 4 and 6	Hourly production meter data logged automatically & reviewed on at least a weekly basis. Data is adjusted to correct gross error when meter/instrumentation equipment malfunction is detected; and/or error is confirmed by meter accuracy testing. Tank/storage facility elevation changes are automatically used in calculating a balanced "Volume from own sources" component, and data gaps in the archived data are corrected on at least a weekly basis.	Conditions between 6 and 8	Continuous production meter data is logged automatically & reviewed each business day. Data is adjusted to correct gross error from detected meter/instrumentation equipment malfunction and/or results of meter accuracy testing. Tank/storage facility elevation changes are automatically used in "Volume from own sources" tabulations and data gaps in the archived data are corrected on a daily basis.	Conditions between 8 and 10	Computerized system (SCADA or similar) automatically balances flows from all sources and storages; results are reviewed each business day. Tight accountability controls ensure that all data gaps that occur in the archived flow data are quickly detected and corrected. Regular calibrations between SCADA and sources meters ensures minimal data transfer error.
Improvements to attain higher data grading for "Master meter and supply error adjustment" component:		to qualify for 2: Develop a plan to restructure recordkeeping system to capture all flow data; set a procedure to review flow data on a daily basis to detect input errors. Obtain more reliable information about existing meters by conducting field inspections of meters and related instrumentation, and obtaining manufacturer literature.	to qualify for 4: Install automatic datalogging equipment on production meters. Complete installation of level instrumentation at all tanks/storage facilities and include tank level data in automatic calculation routine in a computerized system. Construct a computerized listing or spreadsheet to archive input volumes, tank/storage volume changes and import/export flows in order to determine the composite "Water Supplied" volume for the distribution system. Set a procedure to review this data on a monthly basis to detect gross anomalies and data gaps.		to qualify for 6: Refine computerized data collection and archive to include hourly production meter data that is reviewed at least on a weekly basis to detect specific data anomalies and gaps. Use daily net storage change to balance flows in calculating "Water Supplied" volume. Necessary corrections to data errors are implemented on a weekly basis.		to qualify for 8: Ensure that all flow data is collected and archived on at least an hourly basis. All data is reviewed and detected errors corrected each business day. Tank/storage levels variations are employed in calculating balanced "Water Supplied" component. Adjust production meter data for gross error and inaccuracy confirmed by testing.		to qualify for 10: Link all production and tank/storage facility elevation change data to a Supervisory Control & Data Acquisition (SCADA) System, or similar computerized monitoring/control system, and establish automatic flow balancing algorithm and regularly calibrate between SCADA and source meters. Data is reviewed and corrected each business day.		to maintain 10: Monitor meter innovations for development of more accurate and less expensive flowmeters. Continue to replace or repair meters as they perform outside of desired accuracy limits. Stay abreast of new and more accurate water level instruments to better record tank/storage levels and archive the variations in storage volume. Keep current with SCADA and data management systems to ensure that archived data is well-managed and error free.
Water Imported:	Select n/a if the water utility's supply is exclusively from its own water resources (no bulk purchased/ imported water)	Less than 25% of imported water sources are metered, remaining sources are estimated. No regular meter accuracy testing.	25% - 50% of imported water sources are metered; other sources estimated. No regular meter accuracy testing.	Conditions between 2 and 4	50% - 75% of imported water sources are metered, other sources estimated. Occasional meter accuracy testing conducted.	Conditions between 4 and 6	At least 75% of imported water sources are metered, meter accuracy testing and/or electronic calibration of related instrumentation is conducted annually for all meter installations. Less than 25% of tested meters are found outside of +/- 6% accuracy.	Conditions between 6 and 8	100% of imported water sources are metered, meter accuracy testing and electronic calibration of related instrumentation is conducted annually, less than 10% of meters are found outside of +/- 6% accuracy	Conditions between 8 and 10	100% of imported water sources are metered, meter accuracy testing and electronic calibration of related instrumentation is conducted semi-annually for all meter installations, with less than 10% of accuracy tests found outside of +/- 3% accuracy.
Improvements to attain higher data grading for "Water Imported Volume" component: (*Note: usually the water supplier selling the water - "the Exporter" - to the utility being audited is responsible to maintain the metering installation measuring the imported volume. The utility should coordinate carefully with the Exporter to ensure that adequate meter upkeep takes place and an accurate measure of the Water Imported volume is quantified.*)		to qualify for 2: Review bulk water purchase agreements with partner suppliers; confirm requirements for use and maintenance of accurate metering. Identify needs for new or replacement meters with goal to meter all imported water sources.	To qualify for 4: Locate all imported water sources on maps and in the field, launch meter accuracy testing for existing meters, begin to install meters on unmetered imported water interconnections and replace obsolete/defective meters.		to qualify for 6: Formalize annual meter accuracy testing for all imported water meters, planning for both regular meter accuracy testing and calibration of the related instrumentation. Continue installation of meters on unmetered imported water interconnections and replacement of obsolete/defective meters.		to qualify for 8: Complete project to install new, or replace defective, meters on all imported water interconnections. Maintain annual meter accuracy testing for all imported water meters and conduct calibration of related instrumentation at least annually. Repair or replace meters outside of +/- 6% accuracy.		to qualify for 10: Conduct meter accuracy testing for all meters on a semi-annual basis, along with calibration of all related instrumentation. Repair or replace meters outside of +/- 3% accuracy. Investigate new meter technology; pilot one or more replacements with innovative meters in attempt to improve meter accuracy.		to maintain 10: Standardize meter accuracy test frequency to semi-annual, or more frequent, for all meters. Continue to conduct calibration of related instrumentation on a semi-annual basis. Repair or replace meters outside of +/- 3% accuracy. Continually investigate/pilot improving metering technology.

Non-validated Water Audits

In the spectrum of quality levels of water audits, two levels exist for water audits that have not undergone a detailed validation assessment: Self-reported and Filtered.

As noted previously, **Self-reported audits** have not been subject to any in-depth review. The quality of a Self-reported audit may be high, particularly if the audit is compiled by a qualified water loss auditor with several years of auditing experience. However, without conducting the data validation process, the actual quality of the audit cannot be verified. Self-reported audits should therefore be considered provisional until Level 1 validated. Datasets that include multiple Self-reported audits should be viewed cautiously and composite results not taken to be representative of the water efficiency performance of the utilities as a group. It is always appropriate for agencies to validate Self-reported audits to make the audit dataset trustworthy and meaningful. It is recognized that some water agencies have not required the validation step due to resource limitations and other reasons. However, individual audits and audit datasets cannot reliably guide water loss control strategies unless they have been validated.

As noted previously, **Filtered audits** have been checked for technical plausibility by employing a screening criteria. Beyond a check on whether or not the audit presents a realistic scenario, the accuracy of input data sources has not been investigated and the individual gradings have not been validated. Filtered audits can be been checked for technical plausibility by subjecting the data to a series of Data Filtering Steps. The below steps were developed as part of a research project that gathered and analyzed 4,575 water audits collected by five US state and regional water agencies from 2010-2014.[1]

[1] *Water Audits in the United States: A Review of Water Losses and Data Validity*, Water Research Foundation Project 4372b (2015)

Table 2 Filters Used to Screen Water Audits in Water Research Foundation Project 4372b

	METRIC	CRITERIA FOR EXCLUSION
Volumetric	Infrastructure Leakage Index	< 1.0
		> 20.0
	Real Losses	< 0 (negative)
	Cost of Non-Revenue Water	> 100% of system operating costs
	Incomplete audit	key fields not filled out
Financial	Customer Retail Cost	more than 2 orders of magnitude off of the data set's median
	Variable Production Cost	more than 2 orders of magnitude off of the data set's median

Of the seven filtering steps listed in Table 2, two such conditions are flagged during the compilation of the audit by the WAS. A negative loss condition results in a red warning message being displayed noting the negative loss condition and guiding the auditor to further review and correct as needed their data inputs. If the audit is incomplete because one or more of the inputs is unpopulated, then the DVS will not be calculated and the WAS will alert the auditor to this condition. One could presume that such incomplete or implausible audits – as identified by the WAS – would not be submitted to a water agency. However, this is not the case as many such audits have been received by agencies during the four year period. Since some water utilities will always attempt to submit these types of incomplete and/or implausible audits, it is incumbent on water agencies to maintain a policy to reject such audits and prescribe actions to ensure that utilities compile a fully and reasonably populated water audit.

The remaining five filtering steps look for audit results that are implausible, yet more subtle in the interpretation of the data. Extreme values of the Infrastructure Leakage Index (ILI) should be scrutinized as being implausible. Utilities with an ILI value less than 1.0 suggests that the utility is operating with leakage control levels less than the technical low amount of leakage achievable. It should be noted that certain water utilities operate with world-class leakage controls and have achieved such low leakage levels that they challenge the derivations of the Unavoidable Annual Real Losses (UARL) parameter which is used to calculate the ILI. Some of these utilities are reporting an ILI of less than 1.0. Such strong leakage control programs are rare, however, – particularly in North America – and usually utilities reporting a sub-1.0 ILI are found to have few or no proactive leakage control practices in place. In these cases, the low ILI is likely due to data error in one or more audit components. On rare occasions, water audits with a sub-1.0 ILI value can be judged acceptable due to the water utility's rigorous leakage control work. However, it is best that the vast majority of water audits with sub-1.0 ILI should be considered implausible, as judged by a lack of robust leakage control activities in the utility.

Utilities with an ILI over 20 are reporting leakage levels over 20 times the technical minimum UARL value. While such values have been realistically encountered around the world, the generally robust water infrastructure in use in North America makes such extremely high leakage levels very unlikely.

The remaining three filtering steps identify high levels of cost. On a volumetric basis, a water audit should be judged implausible if the Non-revenue Water cost is greater than 100% of the Cost of Operating the System. This represents an extreme case where the vast majority of system expenditures are lost due to leakage. On a financial basis the Customer Retail Cost and the Variable Production Cost can be judged to be implausible if these values are more than two orders of magnitude greater than the median of the entire dataset collected by the Georgia EPD. It is very unlikely that a water utility could be operating with the cost charged to its customers, or the cost of the produced water is more than 100 times greater than the median value of the water utilities in its state or region.

The extreme values of the ILI or various costs represent thresholds for which utility audits meeting such conditions should be rejected by the agency and returned to the utility to reassess their data inputs and hopefully identify and correct error(s) that are producing the implausible results.

Filtering applies analytics to a water audit dataset in an expeditious manner to screen audits that require a closer look by the utility. Filtering is valuable by identifying audits with egregious errors that should be corrected before the more rigorous validation process launches. Table 3 lists the number of audits referred back to the utility after filtering. It is notable that the agencies with the lowest exclusion rates are Georgia and Tennessee, states that invested heavily in training (GA, TN) and data validation (GA).

Table 3 Excluded audits by region for all audits to date – Water Research Foundation Project 4372b

Entity	California	Delaware River Basin Commission	Georgia	Tennessee	Texas
Total Audits Submitted	300	515	452	629	2,662
# of Audits Excluded	100	130	74	122	1,065
Portion Excluded Audits	33%	25%	16%	19%	40%

Summary – the Value of Validation

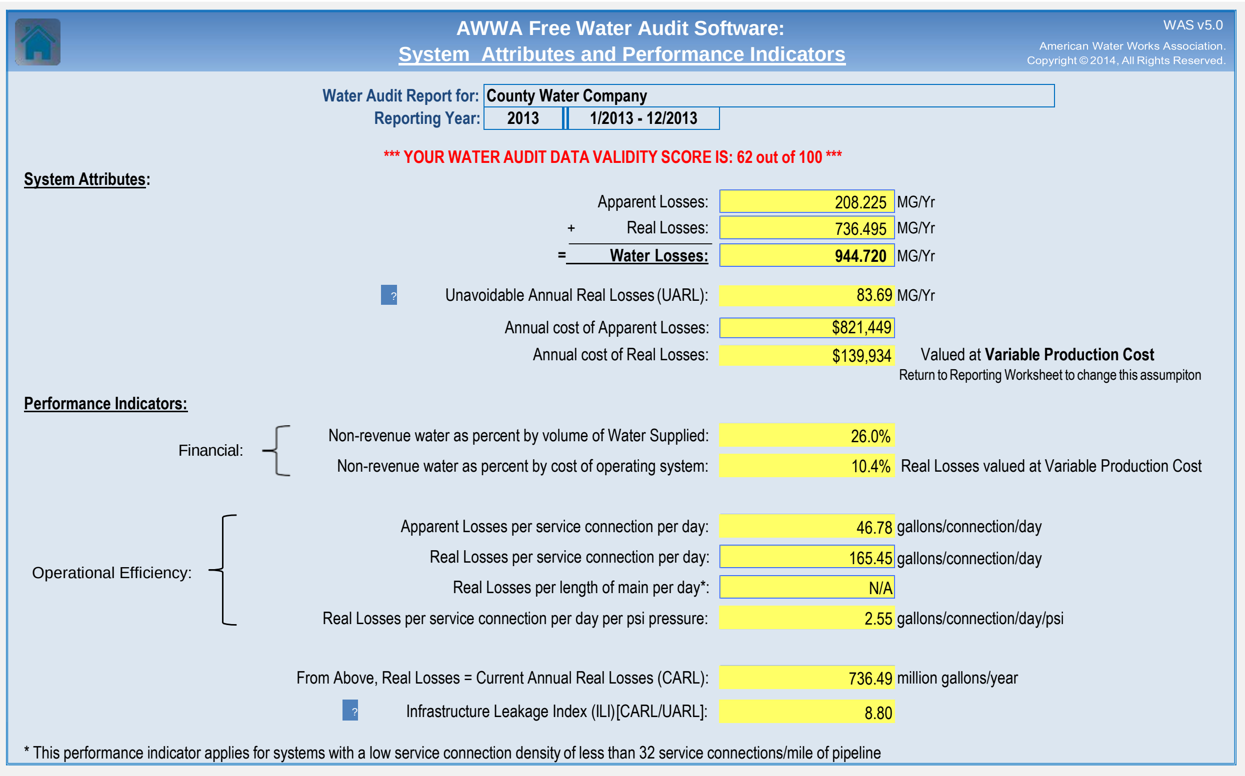
Since North American state and regional water agencies started in 2005 to collect water audit data using best practice approaches, it has become evident that strictly Self-reported water audit data often includes water audits with incomplete or implausible numbers, and/or data that is not representative of the performance of their systems. The creation of the data grading capability and Data Validity Score in the AWWA Free Water Audit Software provided water utilities with a standardized means to assess the validity of their water audit data. However, the greatest value of the water audit process to date is the work – particularly in the State of Georgia – that validates water audits by using a knowledgeable qualified auditor to validate the results – which can be internal or external to the water utility - to produce a representative water audit. The three levels of data validation are explained in this section. These training materials include descriptions of each level of data validation. Level 1 validation is the most widespread validation work conducted to date for North American water utilities, and the appropriate starting point for utilities that have submitted a Self-reported water audit. Water utilities can then move to Level 2 and Level 3 validation processes, as deemed appropriate to improve their audit data validity and refine their Non-revenue water control efforts.

3.2 AWWA Standard Water Audit System Attributes and Performance Indicators: Interpretation of System Performance and Data Quality

The AWWA Free Water Audit Software (WAS) calculates a variety of parameters that are highly effective in the assessment of utility water efficiency. After data is input into the WAS, the software calculates the volume of apparent losses, real losses, water losses, Non-revenue water and the cost impacts of these quantities. Collectively these are the *System Attributes* of the water audit, and they function as the “vital signs” of the utility operations. The WAS also calculates an array of effective performance indicators that allow water stakeholders to objectively assess water efficiency performance of a single utility, or group of utilities. It is very important that utility and other water stakeholders have reliable performance indicators for each of the major components of Non-revenue water and not attempt to assess water efficiency via a single parameter. Since the water audit requires data from many different operational areas within the water utility, it is not possible to reliably assess utility performance with a single output measure.

Figure 1 shows the System Attributes and Performance Indicators Worksheet of the WAS. It is important for the *utility* auditor to carefully review the system attributes and the performance indicators after the data inputs are populated in the WAS in order to ensure that they have reliably entered the data input. It is also important for the *qualified* auditor to scrutinize these values with respect to the utility performance, and in comparison with industry peer datasets. **This is a necessary part of the Level 1 Validation process and should be conducted at the beginning of the process**.

Figure 2 System Attributes and Performance Indicators Worksheet of the AWWA Free Water Audit Software, Version 5.0


AWWA Free Water Audit Software:
System Attributes and Performance Indicators
WAS v5.0
American Water Works Association.
Copyright © 2014, All Rights Reserved.

Water Audit Report for: County Water Company
Reporting Year: 2013 | 1/2013 - 12/2013

*** YOUR WATER AUDIT DATA VALIDITY SCORE IS: 62 out of 100 ***

System Attributes:

Apparent Losses:	208.225	MG/Yr
+ Real Losses:	736.495	MG/Yr
= **Water Losses:**	**944.720**	MG/Yr
Unavoidable Annual Real Losses (UARL):	83.69	MG/Yr
Annual cost of Apparent Losses:	$821,449	
Annual cost of Real Losses:	$139,934	Valued at **Variable Production Cost** Return to Reporting Worksheet to change this assumpiton

Performance Indicators:

Financial:	Non-revenue water as percent by volume of Water Supplied:	26.0%	
	Non-revenue water as percent by cost of operating system:	10.4%	Real Losses valued at Variable Production Cost
Operational Efficiency:	Apparent Losses per service connection per day:	46.78	gallons/connection/day
	Real Losses per service connection per day:	165.45	gallons/connection/day
	Real Losses per length of main per day*:	N/A	
	Real Losses per service connection per day per psi pressure:	2.55	gallons/connection/day/psi
	From Above, Real Losses = Current Annual Real Losses (CARL):	736.49	million gallons/year
	Infrastructure Leakage Index (ILI) [CARL/UARL]:	8.80	

* This performance indicator applies for systems with a low service connection density of less than 32 service connections/mile of pipeline

Assessing System Attributes

The system attributes have the most relevance for the utility itself. There is some value in comparing the system attributes with the water audit data of other water utilities but this is best done with systems of similar size or characteristics. Since there is a wide variety of systems by size and structure the system attributes are most useful for comparisons when limiting them to similar peer utility data. The system attributes of a utility may also be referenced relative to the summary statistics of a dataset of utility data. This can give the utility perspective on where their system stands among a larger group of utilities, even if systems of varying size are included. The system attributes of the water utility include:

- Apparent loss volume
- Real loss volume
- Water losses
- Unavoidable Annual Real Loss (UARL)
- Apparent loss cost
- Real loss cost

Utilities benefit from tracking these values from year-to-year. Losses (both apparent and real) change from year-to-year, either in an increasing or decreasing manner. If the water utility does not have effective loss control interventions in place, the losses will tend to increase, particularly if aggravating factors (ex: cold winter weather promoting leakage, a large water rate increase results in a backlash surge in unauthorized consumption) take place during the audit year. With effective loss control interventions in place, however, the utility will hopefully see a downward trend in these losses.

The impacts of apparent and real losses are reviewed below:

- Apparent Losses: by volume and by cost
    - Water reaches the customer but doesn't (fully) recoup revenue
        - Revenue goes uncaptured
        - Billed authorized consumption is understated
        - Losses occur at the customer retail rate
- Real Losses: by volume and by cost
    - Water is lost from the distribution system before reaching a use

- ➢ Production costs are wasted (or potential sales to new customers is lost if the water is valued at the customer retail rate, which is appropriate where water resources are scarce)
- ➢ Many other negative impacts due to leakage (damage and disruption in commerce from large water main breaks, icing on roadways in cold seasons, utility damage, other)

In addition to knowing its losses on an annual basis, it is also highly important that the water utility calculate the cost of losses each year. Unfortunately, costs mostly tend to rise, so water utilities are usually working against upward cost pressures. It is not unusual for a water utility to see a decrease in losses (apparent and/or real) in a given year, but still see an increase in the cost impacts since cost rates rose during the audit year. Knowing the costs is also essential for the utility to calculate annual economic assessments including benefit:cost ratios, program payback periods, or other economic evaluations.

Water efficiency stakeholders should be mindful of the important cost relationships noted below:

- Apparent Losses: Valued at the customer retail rate
  - When customer billing rates are increased, the cost of apparent losses also increases
- Real Losses: Valued at the marginal production cost (Unless water resources are scarce, then the customer retail rate should be applied to real losses)
  - When productions costs (electric power for pumping, treatment chemicals) increase, the cost of leakage increases

    or
  - When customer billing rates are increased, the cost of real losses also increases (if the customer retail rate is applied to leakage)

Because losses change each year and costs change most years, it is essential that the water audit be compiled on an annual basis. Water utilities can observe their year-to-year performance by placing water audit data annually in the AWWA Compiler Software. This software includes useful worksheets that create charts of most of the input parameters, gradings, system attributes and performance indicators and is highly useful for water utility to trend its performance over time and observe effects of its loss control efforts.

Figure 3 shows the trend of apparent loss volume over five years for the Greater Cincinnati Water Works. In this chart the reduction in apparent losses in the two recent years is noteworthy. It is worthwhile to compare this chart to Figure 4 which charts the customer retail cost rate and Figure 5 which shows the apparent loss costs for GCWW. Figure 3 shows that the customer retail rate for GCWW has risen for each of the years in the water audit history. However, Figure 4 shows that the cost of apparent losses for the two recent years has declined. Thus, GCWW has been able to reduce the volume of apparent losses sufficiently to achieve a reduction in apparent loss costs even in the face of the upward cost pressure of annual customer billing rate increases.

GCWW can thus evaluate its apparent loss reduction program each year in terms of the apparent loss volume and its cost impact. As apparent losses reduce, the cost impact of the losses reduce, and, hopefully the utility should witness an increase in revenue capture.

Figure 3 Apparent Loss (Volume) Trend for Greater Cincinnati Water Works (GCWW) using the AWWA Compiler Software, Version 5.0

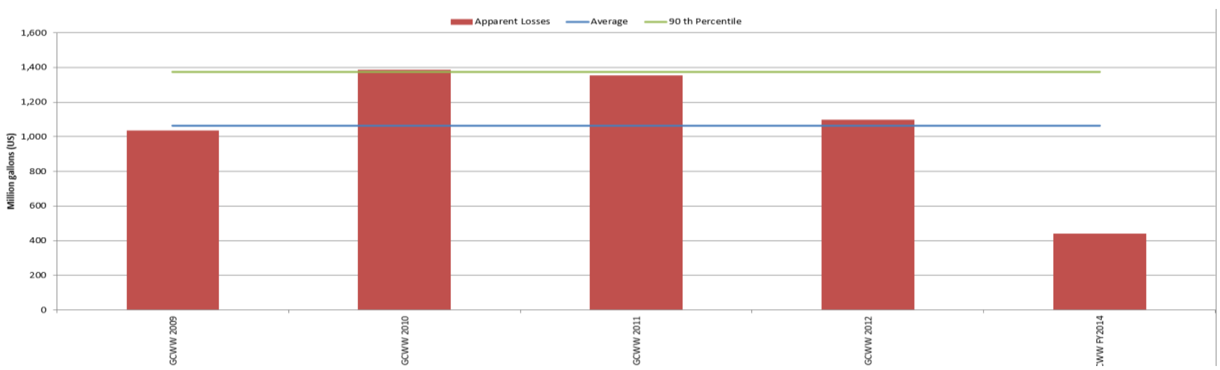


Figure 4 Apparent Loss (Customer Retail Cost) Trend for Greater Cincinnati Water Works (GCWW) using the AWWA Compiler Software, Version 5.0

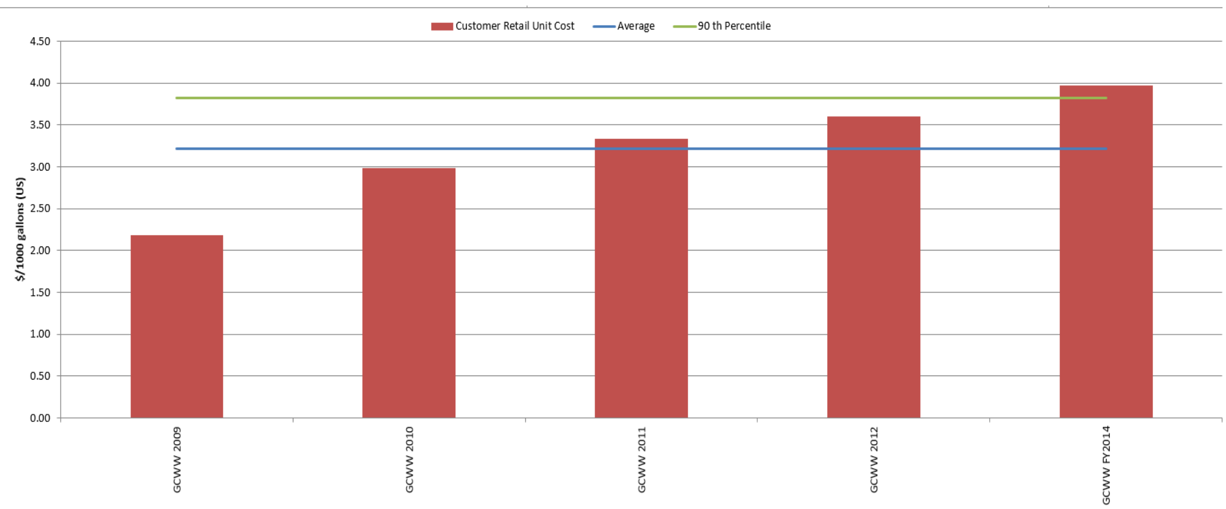
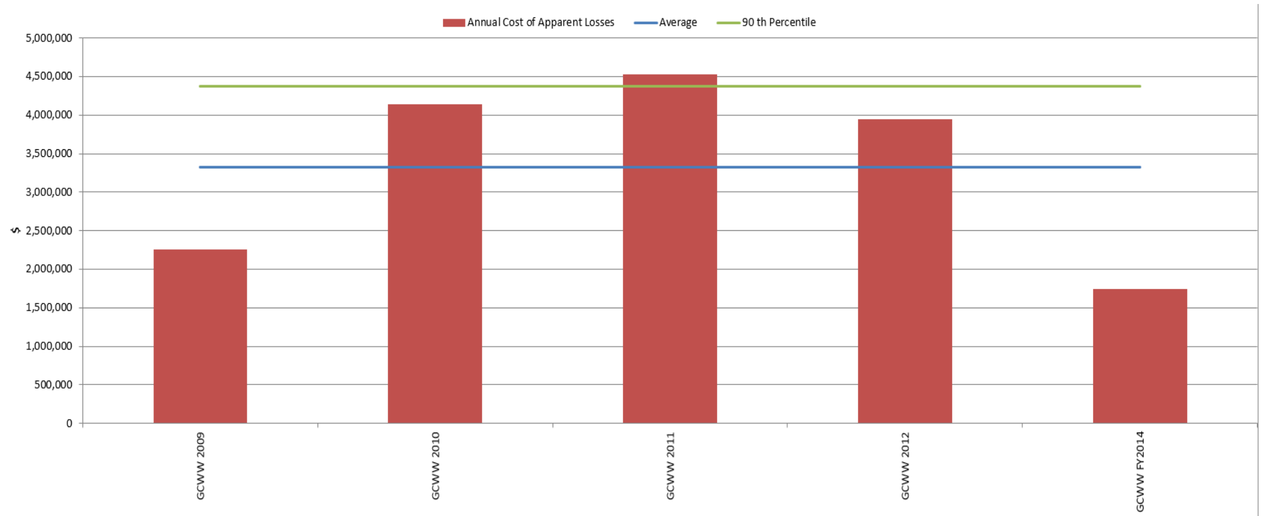


Figure 5 Apparent Loss (Costs) Trend for Greater Cincinnati Water Works (GCWW) using the AWWA Compiler Software, Version 5.0



There is great value for a water utility to carefully track its system attributes from year-to-year, and the Compiler Software is an outstanding tool to carefully track these parameters and assess trends.

Assessing Performance Indicators

The AWWA Water Audit Methodology performance indicators have relevance for the water utility in assessing its own program, also in making performance comparisons with other water utilities. The performance indicators include two broad types: financial and operational.

Financial Performance Indicators

The financial indicators are designed to be used only for high level, financial assessments of water utility operations and should not be used in making assessments of the operational efficiency of the system. The financial performance indicators are simplistic percentage indicators. *Percentage indicators are known to be unduly skewed by varying levels in the authorized consumption value from year-to-year.* Wide swings in consumption can cause these percentages to increase or decrease without any actual change in loss levels. **Hence these indicators should be interpreted cautiously**.

Table 4 shows a listing of the financial performance indicators for the 2013 dataset that includes validated water audits from the State of Georgia (226 systems serving population greater than 3,300). Note that median values are presented in this table along with average values. Since the dataset includes water utilities of widely varying size and characteristics, average values may tend to be skewed upward by some of the utilities with data of very high magnitude. Just a few numbers of high magnitude in the dataset can notably increase the average value for an individual parameter. The extreme values of the maximum and minimum values show how average values can be distorted. The median is therefore more representative of the central tendency of the parameters, since it is the value in which one half of the quantities are above and one half below this value. Perhaps because these statistics are drawn from a reasonably large dataset, the values can be interpreted more objectively than comparing only two systems' financial indicators.

The statistics on the financial indicators show an interesting contrast between the presentation of Non-revenue water by volume vs. Non-revenue water by cost, with the cost impact notably lower percentage than the volume impact. On an individual basis, a utility can compare its financial performance indicators with the summary statistical values for the Georgia dataset shown in Table 4. In this way the utility can make an approximate judgment on their data relative to the composite statistics.

Table 4 Summary Values of the Financial Performance Indicators of the 2013 Water Audit Dataset of the State of Georgia (n=226 systems)

Financial Performance Indicators	Median	Average	Maximum	Minimum
Non-revenue Water by Volume,%	23.1	25.0	100*	4
Non-revenue Water by Cost,%	6.4	7.6	61.6	0.7

*did not report a value for billed authorized consumption

The AWWA Water Loss Control Committee recommends against use of percentage indicators for operational assessments, so any review of the financial performance indicators should be considered as the preliminary review and should be followed by a closer assessment of the operational performance indicators of the utility.

Operational Performance Indicators

The operational performance indicators can be used to make objective assessments for water loss levels in utilities. The indicators can be used for performance tracking of a utility or utilities, and for benchmarking among utilities. Included are indicators to assess both apparent losses and real losses.

Table 5 shows a listing of the apparent loss system inputs and operational performance indicators based on summary guidelines from validated datasets across the United States. In assessing apparent losses an individual water utility can easily see where their values stand within the data range. The value of Apparent Losses Normalized provides perhaps the most useful assessment, both for performance tracking and as an informal benchmarking indicator. It is also helpful and necessary to assess where the utility's customer retail cost is within the dataset. This factor alone can have the greatest impact in setting the apparent loss control strategy. High customer retail costs mean apparent losses are costing the utility in comparatively higher uncaptured revenue. Hence, even water utilities with a relatively low volume of apparent losses may be incentivized to strive for further apparent loss reductions if their customer retail rate is high. This is where the ability to define an economic level of apparent loss is most useful.

Particularly for utilities whose value of apparent losses normalized and customer retail rate both fall above the median value in Table 5, consideration should be given to enhanced apparent loss control activities. It is very likely that notable revenue recovery potential exists in the utility.

Table 5 – Typical Ranges from the Georgia Dataset of the Apparent Loss Operational Performance Indicators & Inputs

Operational Performance Indicators/Inputs	Minimum	Maximum	Median
Apparent Losses Normalized, gal/conn/day	2	15	5
Customer Retail Cost, $/1,000 gal	2	10	4

Table 6 shows a listing of the real loss system inputs and operational performance indicators based on summary guidelines from validated datasets across the United States. The AWWA Water Audit Method includes one performance indicator for apparent losses, but has several indicators for real losses, including the real losses normalized, real losses normalized by level of pressure, and the Infrastructure Leakage Index (ILI).

The real loss normalized indicator has two forms: a standard one expressed in units of gal/service connection/day; and a low service density form expressed in units of gal/mile of pipeline/day. Similarly, these two forms also exist with the pressure normalized indicator.

The ILI is a unit-less indicator that is designed for benchmarking comparisons among utilities. It is the ratio of the level of current annual real losses (CARL) over the unavoidable annual real losses (UARL). The UARL is a theoretical reference level of leakage that represents the technical low level of leakage that a utility could achieve if it employed all available leakage control technologies. Thus, the ILI is a ratio of the utility's current leakage level to its technically achievable low level of leakage. As theoretically derived, the lowest value of ILI that is achievable is 1.0. However, some utilities with very advanced leakage control are driving down leakage so low that their ILI is below 1.0. In this case these systems may be proving that leakage levels can go below the levels commensurate with the leakage allowances devised in the UARL equation. Further research may be needed to update the UARL equation based upon the work by these utilities. Unfortunately, many utilities that have calculated values of ILIs below 1.0 do not have extensive leakage controls in place. For these systems it is likely that their water audit data has embedded error; either the Water Supplied Volume is under-stated, or the Billed Authorized Consumption and/or Apparent Losses are over-stated (or some combination there-of). These systems should carefully review their water audit data for errors.

It should be noted that both the UARL and ILI are system-specific parameters. The UARL is calculated from an equation that includes as inputs the length of the water distribution system pipeline, the number of customer service connections, the average pressure, and the average length of customer service piping maintained by the customer. Since the UARL, and therefore the ILI, are influenced by the average pressure, these values can vary strictly with changes in the average pressure value. Therefore, it is best if the ILI is used for comparisons only after the water utility has conducted work needed to optimize water pressure levels. Otherwise, changes in the ILI may occur only because the average pressure has changed in a given year, and not necessarily because leakage levels have changed.

Table 6 - Typical Ranges from the Georgia Dataset of the Real Loss Operational Performance Indicators & Inputs

Operational Performance Indicators/Inputs	Minimum	Maximum	Median
Real Losses Normalized, gal/conn/day	20	100	40
Real Losses Normalized, gal/mile/day	700	3000	2000
Variable Production Cost, $/million gal	200	1000	400
Infrastructure Leakage Index, ILI	2	10	3

Since the variable production costs vary so widely, there is economic incentive for utilities with high costs to drive down their leakage level to the economic level, which is a value that should be determined by the utility, and usually exists somewhere above the reference level of the UARL. Water utilities can make use of the free software tool developed as part of the Water Research Foundation Project 4372a to determine economic leakage control activities.2 By inputting data on leakage occurrences in the utility, as well as various costs, the tool calculates the economically viable level of leakage management activities – including proactive leak detection and pressure management – to guide the water utility.

Particularly for utilities whose value of real losses normalized and variable production costs both fall above the median value in Table 6, consideration should be given to enhanced leakage management activities. It is very likely that notable leakage reduction potential exists in the utility. This can save water resources and reduce the production expenses incurred by the water utility.

Summary – AWWA Standard Water Audit System Attributes and Performance Indicators: Interpretation of System Performance and Data Quality

As part of the efforts to filter utility water audit data and to conduct Level 1 Validation, the qualified auditor should include a careful review of the System Attribute and Performance Indicator values that are calculated by the AWWA Free Water Audit Software. The qualified auditor should also make use of the summary data of validated water audit datasets to use for reference interpretation of the attributes and indicators. The AWWA Water Audit Data Collection Initiative (WADI) and the State of Georgia water audit data (2011-2013) are currently the only two validated water audit datasets in the United States.

By comparing the utility audit data to the dataset(s), perspective can be gained on the meaning of the System Attributes and Performance Indicators calculated for the water utility. If the utility has values that exist in the extreme ranges of the dataset, or certain combinations of values are in the extreme range of the dataset, then the qualified auditor should pursue a detailed line of questioning of the water utility in the particular area of the water audit.

The close review of System Attributes and Performance Indicators by the qualified auditor is a very useful way to truth water audit data as a preliminary step in the Level 1 Validation process.

[2] *Real Loss Component Analysis: A Tool for Economic Water Loss Control*, Water Research Foundation, Project 4372a, 2014.

The qualified auditor should review validated datasets to come to learn the typical ranges of water audit component values and the limits of the extreme values. This activity will bring additional rigor to the validation process.

3.3 Level 1 Validation of the Inputs that Calculate the Water Supplied Volume

The Water Supplied Volume is the annual quantity of treated drinking water that enters the water distribution system and has the opportunity to reach customer end-users. This volume is the largest volume in the water audit and is of great importance since error in this quantity is carried though the entire water audit. It is very important that the quantity calculated for Water Supplied be as accurate as possible, therefore, the various inputs contributing to this volume should be as accurate as possible. Poorly managed flowmeters generally result in under-registration of flows and an under-stated Water Supplied Volume. In this case the volume of losses can be erroneously under-stated also.

As shown below and as calculated by the WAS (see the section of the Reporting Worksheet in Figure 1), the Water Supplied Volume is calculated as a composite volume from three primary components, and the master meter error adjustment volume that exists for each of the three primary components. Thus, up to six numbers can contribute to the calculation of the Water Supplied Volume. These are:

Volume from Own Sources +/- Volume from Own Sources Master Meter & Supply Error Adjustment

plus

Water Imported +/- Water Imported Master Meter & Supply Error Adjustment

minus

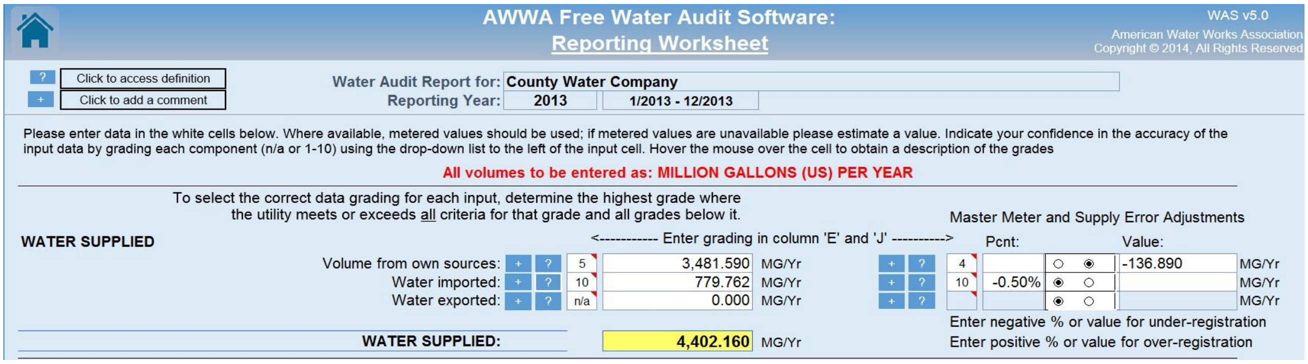
Water Exported +/- Water Exported Master Meter & Supply Error Adjustment

---

equals **Water Supplied Volume**

As noted in the WAS, the auditor can enter a percentage or a volume quantity when providing inputs for the master meter and supply error adjustments for each of the three components of Volume from own Sources, Water Imported, and Water Exported. A negative value is entered when the metered volume is believed to be under-registering, and a positive value is entered when the metered volume is believed to be over-registering.

Figure 6 Water Supplied Components on the Reporting Worksheet for the AWWA Free Water Audit Software, Version 5.0



Production/Supply Metering and Data Management in Water Utilities

Water utilities employ a variety of meter types to measure the bulk flows that convey water supplied from own sources, water imported, and water exported. Certain meter types are generally applied for higher flow applications vs. medium- and low-flow applications, as shown in Table 7. All meter types have specific characteristics in measuring flows, with varying performance strengths and certain limitations. Proper sizing of the meter for the expected flow range is also important. Thus, having an improper size or type of meter can result in inaccuracy of the flow measured by the flowmeter.

Table 7 Common Types of Meters used as Flowmeters to Measure Supplied, Imported, and Export Bulk Water Supplies in Water Utilities

Meters used in High Flowrate Applications	Meters used in Medium, Low Flowrate Applications
Venturi	Turbine
Orifice Plate	Propeller
Electro-Magnetic	Positive Displacement
Ultrasonic	

Many thousands of flowmeter installations exist throughout the United States. Unfortunately, many flowmeters installations are:

- Improperly typed
- Poorly sited
- Rarely have maintenance conducted on the meter
- Seldom tested for accuracy
- Producing data taken verbatim as accurate by utility personnel

Figure 2 - 36-inch Venturi Meter

(Courtesy of Primary Flow Signal)

The Water Supplied Volume is the most important quantity in the water audit; yet flowmeter installations are often neglected or poorly managed assets. Hence the measured flows that are produced by flowmeters may suffer compromised accuracy. Since these meters produce the largest quantities in the water audit, even a very small degree of error can represent a significant amount of water volume that is erroneous. Water utilities should assess their flowmeter installations and give these assets a high level of focus in their maintenance and operations activities.

Water utilities should have a good handle on their flowmeter demographics, or the information on the existence and characteristics of the flowmeters in the system. Utilities should maintain detailed information on these assets, including: their locations, piping configurations, size, type, and manufacture of the flowmeter and its secondary instrumentation. Good meter accuracy and instrument calibration records should be maintained. If utility personnel don't have good information on their production meters, the first step should be to conduct a physical inventory of the meter sites. Visit the sites and inspect the flowmeters, take photographs, record the information found on nameplates, observe electronic or hydraulic connecting lines and instrumentation. Check files in the main office for purchase or maintenance records. Assemble all possible information in a file and begin activities for accuracy testing, repair and/or replacement of various flowmeters.

The measured volumes produced by flowmeters can have notable inaccuracies. Additionally, the collective data produced by multiple flowmeters in the system is not always reliably tracked and balanced across the distribution system to produce an accurate Water Supplied volume. On a daily basis, the Water Supplied Volume is not only a function of the volumes produced by the treated water flowmeters, but also the net flow impacts of supply to tanks and storages, and, possibly, supplies into and out of pressure zones and District Metered Areas (DMA), all of which depend upon the configuration of the water distribution system and number of bulk metering points throughout the system. Utilities should be familiar with their detailed water distribution system configuration and maintain operational reports that can tally the daily Water Supplied Volume for the system. These daily values should be reviewed and corrected as needed on a regular basis so that monthly and annual reporting of supplied volumes is accurate.

Flowmeter Accuracy Testing: Verification and Calibration

Since the Water Supplied Volume is such an important quantity to the accuracy of the utility water audit, the flowmeters that generate the measured flow data should be maintained and regularly tested for accuracy. As discussed later in this section, rigorous and routine flowmeter accuracy testing is necessary in order to justify high data gradings in the WAS. Use of meter accuracy test results is needed to quantify the Master Meter & Supply Error Adjustment components of the water audit. Good data management of the supply data across the system and making adjustments for data gaps and flow balancing errors should also be included in the MMSEA component for Volume for Own Sources.

Several reliable methods exist to test flowmeters in water utilities[3]. The primary methods include:

- Take the flowmeter out of service and send it to a meter testing facility
- Test the flowmeter in-situ by running flow through a calibrated test meter in an outfitted truck (Figure 7).
- Install a portable meter in series with the existing meter and obtain two sets of measurements over a minimum 24-hour period (Figure 8).
- Conduct a reservoir drop test if the flowmeter exist adjacent to a water storage facility and the pipe configuration is acceptable (Figure 9)
- Use the Mass Balance Technique (although this is more of a process control check than an actual meter accuracy test method).

[3] AWWA. 2016. Manual M36 (4th Ed), Water Audits and Loss Control Programs. Denver, Colo.: American Water Works Association

Methods listed as 1 and 2 (Fig 7) above apply to medium- and small-sized meters of approximately 20-inch and smaller. For Method 1, a brief pipeline shutdown is executed to remove the flowmeter and replace it with a meter of the same type. The meter to be tested is then sent to a meter test facility. A downside to this approach is that the meter is tested in laboratory conditions and any disturbances existing in the field location of the meter will not exist during the accuracy test. Removing and transporting meters larger than 20-inch to test facilities is usually not practical.

Method 3 (Fig 8) is virtually the only means to test large flowmeters sized 24-inch and above.

Accurate results can be achieved in conducting a reservoir drop test (Method 4), which is a volumetric test in which inflow to a reservoir, tank, or storage basin (Fig 9) is halted and only outflow exists for a period of several hours. The entire outflow must pass through the meter being tested. The drawdown in the storage facility over the period of the test is converted to a volume and average flowrate that can be compared to the measured volume recorded by the meter over the same period. Unfortunately this test can only be conducted by utilities that have an acceptable configuration of storage, piping, and flowmeter to allow this procedure.

The Mass Balance technique (Method 5) compares flows from two or more flowmeters in series. Usually the relative difference in flows shows a steady pattern. When this difference begins to change notably, it could mean that one of the meters is beginning to lose its typical accuracy level.

Figure 7 Meter testing via truck mounted apparatus

(Courtesy of Louisville Water Company)

Figure 8 Pitot rod inserted into large pipeline

Figure 9 Reservoir or clearwell adjacent to a water treatment plant

Flowmeter Accuracy Verification vs. Secondary Instrumentation Calibration

Flowmeter installations typically consist of a primary measuring element (the flowmeter) and a secondary device, which may be a differential pressure cell, chart recorder, or other device which receives the input from the flowmeter. Figure 10 shows a cross section of a typical water flowmeter installation.

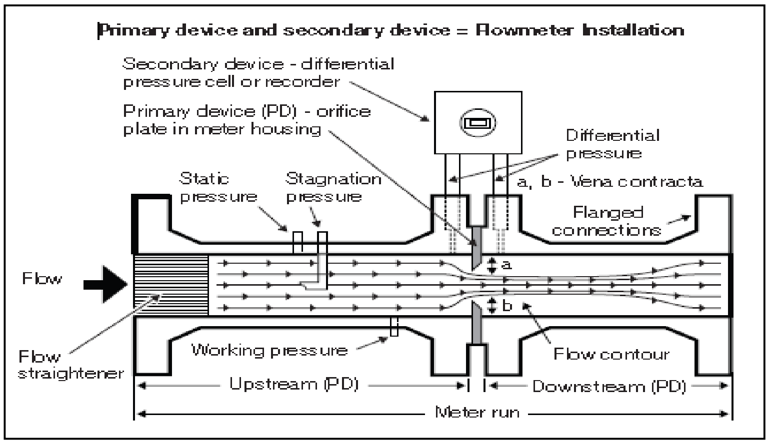


Figure 10 Orifice Plate Flowmeter components

(Source: AWWA M36 Publication, 4th Ed.)

Figure 11 shows a bank of differential pressure (DP) cells connected to several venturi flowmeters. These DP cells are connected to water sensing lines from the venturi. The cell senses the differential pressure generated by the venturi flowmeter and converts this value to a flow and equivalent electronic signal.

DP cells should undergo regular calibration to make sure that their capability to create an output signal from the input is accurate. However, this calibration function does nothing to test the accuracy of the water pressure being generated by the venturi flowmeter. Calibration merely confirms the secondary device, not the primary – metering – device.

Fig 11 Bank of Differential Pressure Cells connected to flowmeters

(Courtesy of Louisville Water Company)

Many water utilities reliably calibrate secondary devices like DP cells and assume that this has confirmed the accuracy of the flowmeter. Unfortunately this is not the case. Utilities should verify the flow measuring capability of the primary device (flowmeter) on a regular basis.

This is one of the most fundamental and important activities of a good water loss control program.

In compiling the AWWA standard water audit, many utilities seems to interpret secondary device calibration as a flowmeter accuracy verification function, which it is not. This is a common misconception. These utilities often select a high data grading for the Volume from Own Sources, Water Imported, and Water Exported based upon regular calibration of secondary devices. However, without conducting a separate accuracy verification of the flowmeter, the highest grading available to the water utility is a 7.

After the Flowmeter – Maintaining Integrity in the Data Trail throughout the SCADA System to Final Reporting

Meter accuracy testing confirms the degree of inaccuracy of the various flowmeters in a utility water supply system. Many utilities include a number of flowmeter installations with a variety of flowmeter sizes and types, each with a different level of accuracy. The degree of inaccuracy should be taken into account by the utility when reporting the annual Water Supplied Volume. Adjustments to the flow data – ideally on a business-daily basis – should be employed to account for these inaccuracies.

In addition to the inaccuracies of the flowmeters, additional data error can occur in the data trail that leads from the flowmeters to the secondary devices, to the SCADA System, and final reporting. Error in the data can be introduced in a variety of manners. In addition to the summation of the flowmeter data, the annual Water Supplied Volume should include flows moved into- and out of- storage facilities like tanks and treated water reservoirs, in a manner tabulated on a daily basis. While tank flows tend to trend in a regular daily pattern and the net inflows/outflow tend to cancel each other, disruptions to the data occur regularly in water systems. Such disruptions can occur when SCADA communications are compromised and data transmission is halted, flowmeters or related instrumentation fail, and SCADA computer equipment interruptions occur. Additionally, events such as storage tank overflows occasionally occur inadvertently, and drinking water is supplied to tank overflows as waste rather than supplied to the water distribution system. All of these events can compromise the daily Water Supplied Volume, hence it is best for the utility to monitor and correct data on a business-daily basis.

The data adjustment method described above can be carried out throughout the water audit year on a regular basis in order to correct data gaps and other data disruptions as they occur. It is recommended to review SCADA system output reports to confirm supply data and detect data gaps and disruptions; and make corrections and data adjustments as soon as possible. Delaying data review (or not conducting this function) creates the opportunity for such disruptions to go undetected and to introduce an uncertain degree of error into the ultimate Water Supplied Volume calculation.

Activities to maintain integrity of the data throughout the entire data trial are included as criteria in the Grading Matrix worksheet of the WAS. These are included in the Master Meter and Supply Error Adjustment component. These activities are included in the hierarchy of activities leading up to a grading of 10, for which the utility must have strict SCADA system tracking and accountability controls with data reviewed each business day. For utilities that do not provide any regular scrutiny of these data, the highest data grading suitable is 3. A utility can improve their processes by modifying their daily procedures to incorporate a review function for daily supply reports. Reviewing supply data on a business daily basis is considered best practice.

Grading the Water Supplied Volume Sub-components

The Grading Matrix includes process based activities that define steps that produce data of high validity, and also operations of high performance. Table 8 lists the six sub-components and the process focus of each sub-component as included in the Grading Matrix worksheet. The general processes include establishing and maintaining reliable flowmeters, regularly testing the flowmeters for accuracy and calibrating their secondary devices, balancing flow data across the water distribution system and providing ongoing data surveillance in order to quickly detect data gaps/disruptions and make data corrections. For imported/exported supplies, the criteria also includes language to ensure that effective written agreements exist between water utilities buying and selling bulk water to each other.

Table 8 The Six Sub-components that are Inputs to the Calculation of the Annual Water Supplied Volume and the AWWA Free Water Audit Software Grading Matrix Criteria

Sub-component	WAS Grading Matrix Focus
Volume from Own Sources	Installing flowmeters on sources, conducting secondary device calibration, conducting meter accuracy testing, and obtaining test results within a tight degree of accuracy
Volume from Own Sources Master Meter and Supply Error Adjustment	Flowmeter output data is regularly monitored and inaccuracies are incorporated into regular data adjustments, flows are balanced across the distribution system with tank levels monitored regularly and data gaps quickly identified and corrections to the data implemented
Water Imported	Installing flowmeters on sources, conducting secondary device calibration, conducting meter accuracy testing, and obtaining test results within a tight degree of accuracy
Water Imported Master Meter and Supply Error Adjustment	Flowmeters are installed and an explicit written agreement exists between the seller of the water and the utility. Flowmeter output data is regularly monitored and inaccuracies from data gaps or disruptions are incorporated into regular data adjustments which are quickly implemented.
Water Exported	Installing flowmeters on sources, conducting secondary device calibration, conducting meter accuracy testing, and obtaining test results within a tight degree of accuracy
Water Exported Master Meter and Supply Error Adjustment	Flowmeters are installed and an explicit written agreement exists between the utility and the utility purchasing the water. Flowmeter output data is regularly monitored and inaccuracies from data gaps or disruptions are incorporated into regular data adjustments which are quickly implemented.

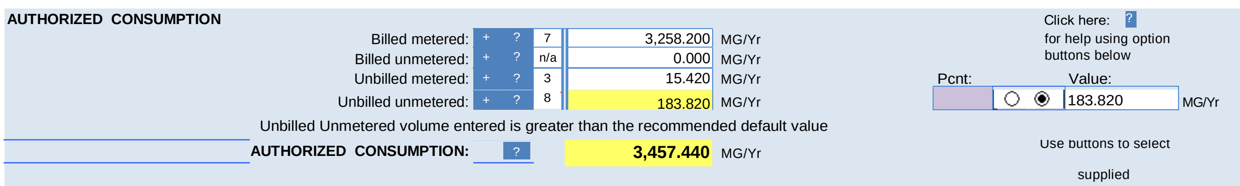
The qualified water loss auditor should become familiar with the criteria of the Grading Matrix in order to objectively assess the operating practices of the utility and assign appropriate gradings to the above sub-components.

3.4 Level 1 Validation of the Inputs that Calculate the Authorized Consumption

The Authorized Consumption Volume is the annual quantity of treated drinking water that is used by customers or other authorized end-users. This volume is usually the second largest volume in the water audit and the difference between it and the Water Supplied Volume is used to calculate the system water losses, so correct and good data is very important. If there are inaccuracies that result in too much water being input into this section of the water audit, the losses may be underestimated.

The volume in this category can be either metered or unmetered and billed or unbilled. These classifications create four input combinations shown in Figure 12 below: Billed Metered, Billed Unmetered, Unbilled Metered, and Unbilled Unmetered. For the unmetered inputs, estimates are used to determine the volume to be entered into the water audit. Refer to Section 2.4 of this manual for more information about entering data into this section.

Figure 12 Authorized Consumption Components on the Reporting Worksheet for the AWWA Free Water Audit Software, Version 5.0



Grading the Authorized Consumption Volume Sub-components

The Grading Matrix includes process based activities that define steps that produce data of high validity, and also operations of high performance. Table 9 lists the four sub-components and the process focus of each sub-component as included in the Grading Matrix worksheet. The general processes include metering of authorized uses, good recordkeeping, and meter testing and replacement. For unmetered uses, the criteria also includes clear written policies, procedures and practices for estimating these uses, and tracking of all the different kinds of authorized uses.

Table 9 The Four Sub-components that are Inputs to the Calculation of the Authorized Consumption Volume and the AWWA Free Water Audit Software Grading Matrix Criteria

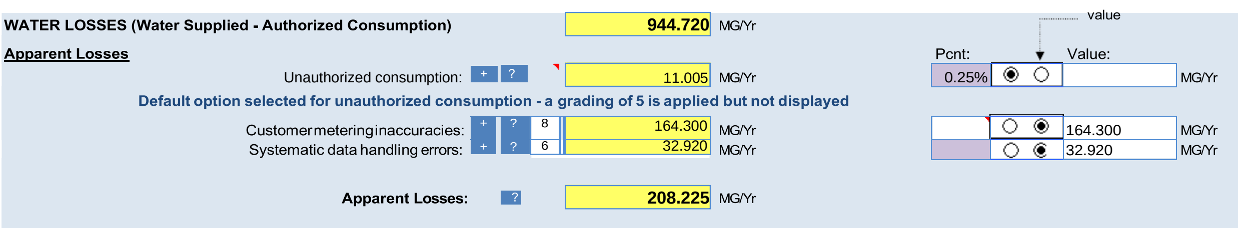
Sub-component	WAS Grading Matrix Focus
Billed Metered	Metering of customers and billing based on volume, meter testing and replacement, good recordkeeping and auditing
Billed Unmetered	Written policies, minimizing unmetered accounts, reliable estimates of unmetered uses
Unbilled Metered	Written policies, meter reading and management, meter testing and replacement, good recordkeeping and auditing
Unbilled Unmetered	Written policies, minimizing unmetered accounts, reliable estimates of unmetered uses, tracking of all types of this use

The qualified water loss auditor should become familiar with the criteria of the Grading Matrix in order to objectively assess the operating practices of the utility and assign appropriate gradings to the above sub-components.

3.5 Level 1 Validation of the Inputs that Calculate the Apparent Loss Volume

The Apparent Loss Volume is the annual quantity of treated drinking water that is used but not properly measured or paid for. They are also sometimes called paper or economic losses. Reducing these losses provide for better accounting and revenue recovery. There are three inputs shown in Figure 13 below: Unauthorized Consumption, Customer Metering Inaccuracies and Systematic Data Handling Errors. Data for these inputs may commonly be estimated, but there are practices listed in the grading matrix that help to improve the accuracy of these numbers. Refer to Section 2.5 of this manual for more information about entering data into this section.

Figure 13 Apparent Losses Components on the Reporting Worksheet for the AWWA Free Water Audit Software, Version 5.0



Grading the Apparent Loss Volume Sub-Components

Table 10 lists the three sub-components and the process focus of each sub-component as included in the Grading Matrix worksheet. The general processes include establishing policies and procedures and implementing field activities for determination and management of subcomponents.

Table 10 The Three Sub-components that are Inputs to the Calculation of the Annual Apparent Loss Volume and the AWWA Free Water Audit Software Grading Matrix Criteria

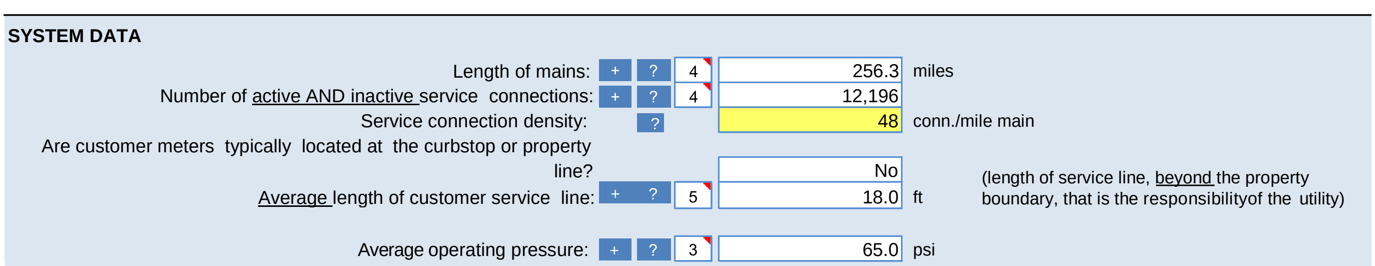
Sub-component	WAS Grading Matrix Focus
Unauthorized Consumption	Policies and procedures to document unauthorized consumption occurrences, policies exist to quantify, qualify and/or manage unauthorized consumption
Customer Metering Inaccuracies	Customer meters are used by the majority of customers, reliable recordkeeping system for customer meters, meter testing and replacement is customary, composite meter inaccuracy is determined from meter testing activities and is used in volume determination
Systematic Data Handling Errors	Policies and procedures to document and track activation and deactivation of billed accounts and meters, frequency of account review, robust computerized billing system with extensive reporting capabilities, examination of billing reports looking for lapses or misses in consumption

The qualified water loss auditor should become familiar with the criteria of the Grading Matrix in order to objectively assess the operating practices of the utility and assign appropriate gradings to the above sub-components.

3.6 Level 1 Validation of the Inputs that Calculate the System Data

The System Data section of the water audit includes utility-specific information for calculation of performance indicators and other metrics generated by the water audit software. There are four inputs shown in Figure 14 below: Length of Mains, Number of Active and Inactive Service Connections, Average Length of Customer Service Line and Average Operating Pressure. Refer to Section 2.6 of this manual for more information about entering data into this section.

Figure 14 System Data Components on the Reporting Worksheet for the AWWA Free Water Audit Software, Version 5.0


SYSTEM DATA

Length of mains:	+ ?	4	256.3	miles	
Number of active AND inactive service connections:	+ ?	4	12,196		
Service connection density:	?		48	conn./mile main	
Are customer meters typically located at the curbstop or property line?			No		(length of service line, beyond the property boundary, that is the responsibilityof the utility)
Average length of customer service line:	+ ?	5	18.0	ft	
Average operating pressure:	+ ?	3	65.0	psi	

Grading the System Data Sub-components

Table 11 lists the four components and the process focus of each component as included in the Grading Matrix worksheet. The general processes include establishing and maintaining sound policies for permitting and activating new water mains and service connections, enacting pressure controls to separate and efficiently operate different pressure zones and field data collection of pressure data and validation of system appurtenances.

Table 11 The Six Sub-components that are Inputs for System Data and the AWWA Free Water Audit Software Grading Matrix Criteria

Sub-component	WAS Grading Matrix Focus
Length of mains	Sound policies and procedures for permitting and commissioning new water mains, regular field validation of water mains, well-kept records and asset management system (GIS based)
Number of active AND inactive service connections	Activation policies and procedures for new service connections, well written billing policies and procedures, field validation of service connections, internal system auditing, connection count in error is less than 1%-2%
Average length of customer service line	Curb stop serves as delineation point between utility and customer ownership of service connection piping, clear written policy exists to define service connection piping responsibility, accurate recordkeeping
Average operating pressure	Pressure controls exist for the system and separate different pressure zones, telemetry monitoring of system pressure, pressure readings gathered by different sources, pressure zones are well delineated, SCADA system exists

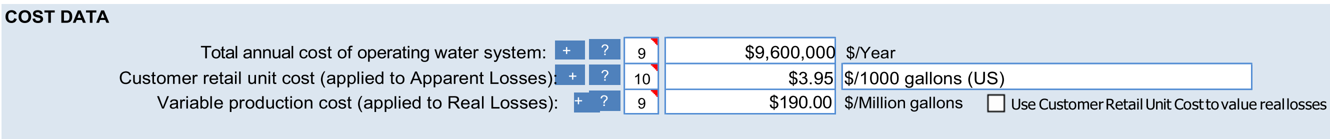
The qualified water loss auditor should become familiar with the criteria of the Grading Matrix in order to objectively assess the operating practices of the utility and assign appropriate gradings to the above sub-components.

3.7 Level 1 Validation of the Inputs that Calculate the Cost Data

The Cost Data section of the water audit includes utility-specific cost information for calculation of performance indicators and other metrics generated by the water audit software. There are three inputs shown in Figure 15 below: Total Annual Cost of Operating the Water System, Customer Retail Unit

Cost and Variable Production Cost. Refer to Section 2.7 of this manual for more information about entering data into this section.

Figure 15 Cost Data Components on the Reporting Worksheet for the AWWA Free Water Audit Software, Version 5.0



Grading the Cost Data Sub-components

The Grading Matrix includes process based activities that define steps that produce data of high validity, and also operations of high performance. Table 12 lists the four sub-components and the process focus of each sub-component as included in the Grading Matrix worksheet. The general processes include reliable electronic accounting system, including all pertinent costs, along with annual auditing. For customer retail and variable production costs, the criteria also includes clearly written up-to-date water rate structure that is based on customer classes and tracking of all variable production or purchase costs, both primary and secondary.

Table 12 The Four Sub-components that are Inputs to the Calculation of the Cost Data and the AWWA Free Water Audit Software Grading Matrix Criteria

Sub-component	WAS Grading Matrix Focus
Total annual cost of operating water system	Using an electronic, industry standard, cost accounting system, including all pertinent water system costs, and annual auditing of financials (preferably by third-party CPA)
Customer retail unit cost	Current, up-to-date water rate structure based on customer classes, composite rate calculation reviewed by third party
Variable production cost	Using an electronic, industry standard, cost accounting system, including all pertinent water system variable operating costs (produced or purchased or both), and secondary costs, annual auditing of financials (preferably by third-party CPA), cost calculation reviewed by third party

The qualified water loss auditor should become familiar with the criteria of the Grading Matrix in order to objectively assess the operating practices of the utility and assign appropriate gradings to the above sub-components.

3.8 Conducting the QWLA Level 1 Validation Review

Flowchart - The overall process for a Level 1 Validation review should follow the steps below.

Step		
1	Obtain audit & supporting documents	
	- documents provided	
	- documents missing	contact auditor to obtain missing documentation
2	Initial Screening of Audit Metrics	
	- run Compiler Software (if multiple years)	run screening
	- no flags from screening	
	- wrong units, missing data	notify auditor: correct units and complete data input
	- real loss volume < 0	return to auditor, or dig into documentation to find the error?
	- other flags from screening	use this to guide your investigative review in steps 2 through 6
3	Review Water Supplied	
	- follow checklist	document answers
	- look for common pitfalls	
	- analyze documentation against grades	document recommended edits as applicable
	- analyze documentation against inputs	document recommended edits as applicable
4	Review Authorized Consumption	
	- follow checklist	document answers
	- look for common pitfalls	
	- analyze documentation against grades	document recommended edits as applicable
	- analyze documentation against inputs	document recommended edits as applicable
5	Review Apparent Loss	
	- follow checklist	document answers
	- look for common pitfalls	
	- analyze documentation against grades	document recommended edits as applicable
	- analyze documentation against inputs	document recommended edits as applicable
6	Review System Data	
	- follow checklist	document answers
	- look for common pitfalls	
	- analyze documentation against grades	document recommended edits as applicable
	- analyze documentation against inputs	document recommended edits as applicable
7	Review Cost Data	
	- follow checklist	document answers
	- look for common pitfalls	
	- analyze documentation against grades	document recommended edits as applicable
	- analyze documentation against inputs	document recommended edits as applicable
8	Final Screening of Audit Metrics	
	- final screening of Performance Indicators for reasonableness	
	- watch for unusually low (<1.0) or high (>20.0) Infrastructure Leakage Index (ILI) values	
	- Is NRW Cost greater than 100% of System Operating Costs?	
9	Assemble water audit file and basis of audit documentation	
10	Complete water loss audit certification statement for EPD submittal	

Technique

The responsibility of the Qualified Water Loss Auditor (QWLA) is to review supporting data and ask questions with utility staff to validate the inputs and the data grades in the water loss audit. This is the essence of Level 1 Validation review described in this document. It's important to recognize that the QWLA may be reviewing the audit in one of three situations:

1) The QWLA is also the person who has prepared the audit
2) The QWLA did not prepare the audit, but works within the utility
3) The QWLA is 3rd party to the utility

No matter the situation, the methodology described in this document applies. In each of the 3 situations described above, the gathering of data and interview questions with various utility staff is necessary. As such, the QWLA's techniques for gathering this information must be professional, and guide any adjustments needed to inputs or grades as a consensus between the QWLA and utility staff. The QWLA should only certify an audit where all inputs and grades have been properly validated and documented per the Level 1 Validation methodology.

Below are the recommended techniques for the validation review of water utility data entered into the AWWA Free Water Audit Software (WAS). Keep in mind there are 2 functions to the validation review: 1) affirming the data grades and 2) affirming the data inputs. Affirming the data grades is a function of matching up the utility's policies, practices & records to the grading criteria in the Grading Matrix worksheet of the WAS – this largely comes from the Q&A with utility staff. Affirming the data inputs is a function of matching up the utility's data to the derivation of the input – this largely comes from review and understanding of the supporting documents. These are 2 independent functions that can simultaneously occur in the validation review.

It is most effective if the validation reviewer can review the utility's supporting documentation in advance of the validation review meeting. Some of the checklist may can be completed from the supporting documentation alone. If the submitted supporting documentation is sparse, the validation reviewer should work to obtain as much as possible before the validation review meeting. Determine what items on the checklist are not explained from the supporting documentation. Then in the meeting, complete the checklist by asking the utility representative(s) gently probing, open ended questions. For example, rather than "do you test your customer meters", ask "tell me about your customer meter testing"; or "how was the retail cost calculated" rather than "was the retail cost a weighted calculation from among all rate codes".

Use the responses and documentation provided to assess the appropriate data grade for each input, which is the highest grade where <u>all</u> of the criteria are met or exceeded. If a grade adjustment (up or down) is made, note this on in the Comments worksheet of the WAS in the final version of the audit. A general guideline is that documentation (as described in the subsequent section) should be provided to support data grades selected in the audit.

Stay alert for common pitfalls in the derivation of the data inputs as well. If an input adjustment is needed, work with the utility auditor to come to agreement on the representative adjusted input during the meeting. Note this on the Comments worksheet in the final version of the audit.

Validation Documentation

The validation reviewer should document all checklist answers and any other pertinent information gained in the review in each respective cell of the Comments worksheet of the WAS or comparable format. In the General Comments cell, the following minimum information should be documented: Name and contact info of validation reviewer, name and contact info of the utility audit preparer(s), reviewer's observations from initial screening of the audit metrics, and any general comments that are relevant.

General Comment:	QWLA: Walter P. Loss, wploss@mwu.org, QWLA #0117. Audit prepared by: Frank Smith, fsmith@mwu.org. Initial screening of metrics: shows metrics to be off by several orders of magnitude. Corrected volume units to MG/yr. Metrics in line with validated datasets.

Audit Item	Comment
Volume from own sources:	From Dale Moorville (Production). Volumes from WTP FWM venturis. Data collected from SCADA archive and recorded in production spreadsheet. The differential pressure cells (transducers) connected to the venturi FWFM are calibrated on a semi-annual basis. The latest accuracy verification tests performed on the 2 FWFMs showed 6.3% over registration on #1 and 1.3% under registration on #2. Meter #1 is a 35 yr old venturi. Meter #2 is a 18 year old venturi.
Vol. from own sources: Master meter error adjustment:	From Dale Moorville (Production). Calculation: 6.3%x71% (over) - 1.3%x29% (under) = 4.1% (over). FWFMs logged daily, reviewed monthly. Data gaps in SCADA have been observed but not accounted for in this input, will correct for future. Flows across the distribution system are balanced automatically by the SCADA System with inflow/outflow of supply at MWU's five ground level water storage tanks taken into account.
Water imported:	n/a
Water imported: master meter error adjustment:	n/a
Water exported:	From Debbie Reaves (Billing). Water sold to Walter County.
Water exported: master meter error adjustment:	From John Collins (Metering). Walter County master meter is not tested. Master meter is an 8" turbine, age unknown. Read monthly.
Billed metered:	From Debbie Reaves (Billing) and John Collins (Metering). 100% of cusomers are metered. Reads conducted quarterly, rate of estimation is approx 14%. Meter population ranges from new to >20 years old. Routine changeout of small meters at approx. 2500 per year; changeout not based on test results. 10% of pulled meters are tested.
Billed unmetered:	From Debbie Reaves (Billing). No flat rate accounts.
Unbilled metered:	From John Collins (Metering). Only 2 metered facilities are unbilled: Smith WWTP and Weston WWTP. The volume of potable water consumed (but not billed) by these facilities in the audit year was 392.4 mg.
Unbilled unmetered:	From Rick Miller (Distribution). Fire dept usage from 3 VFDs reported monthly, but the largest of the 3 is deemed unreliable. Flushing volumes are tracked by MWU staff each month. Calculation: Fire Dept (4.5mg) + Flushing (15.48mg) = 29.98 mg.
Unauthorized consumption:	Default utilized, this item is not tracked closely.
Customer metering inaccuracies:	From John Collins (Metering). 10% of the roughly 2500 meters pulled for replacement each year are tested. Majority of these are small meters. Selection for replacement not based on testing data, but rather age or area of the system. Overall inaccuracy calculated from test results in audit year was 3.93%.
Systematic data handling errors:	Default utilized, this item is not tracked closely.
Length of mains:	From Chris Johnson (Engineering). GIS system in place, solid process exists for permitting new construction and obtaining as-built records in a timely fashion. Follow-up field checks to confirm the as-built drawings are not conducted very often, however, and occasionally errors or omissions in the final records are noted by field staff when they are conducting work on the system.
Number of active AND inactive service connections:	From John Collins (Metering). MWU has a system of dated paper records for customer service connection lines installed before 1990. This data is of poor quality and the number of In-active service lines (6,500) is very approximate. Records of lines installed after 1990 generally have more accurate data and this information is also included in the computerized customer billing system. The total number of customer service lines is believed to be in error by 5-10%.
Average length of customer service line:	From John Collins (Metering). All customer meters are installed at the property line, default input of zero here.
Average operating pressure:	From Rick Miller (Distribution). Pressure data is collected only from periodic hydrant flow tests and at the water plants. The network is setup in 6 pressure zones. Average operating pressure is determined as a simple average of available readings.
Total annual cost of operating water system:	From Jen Stevens (Finance). Water Budget Summary report for FY 2014. Includes depreciation and debt service, excludes non-potable operating costs. All financial records are audit by the MWU staff and an outside CPA firm each year.
Customer retail unit cost (applied to Apparent Losses):	From Jen Stevens (Finance). Calculation: 4011.72/6251.50 = 64% ratio of sewer to water sold $4.65 + ($5.81x64%)= $8.38/kgal Only residential rates utiltized in calculation, volume sold by rate codes not readily available in billing software.
Variable production cost (applied to Real Losses):	From Jen Stevens (Finance). Calculation: Chemicals ((1,093,145.38)+Electricity (2,263,889.57)) / 8250.44 MG produced = $406.89/MG. Includes chemicals and electricity only.

1. **STEP 1 – Obtain Supporting Documentation**

The documentation described in this section should be obtained where available from the auditor to facilitate the Level 1 Validation review. If some of the documents noted below are not available, the reviewer should note this in the validation form accordingly. A general guideline is that documentation should be provided to support data grades selected in the audit. Note: some documentation can be easily recorded in the Comments worksheet of the WAS, and other documentation may need to be submitted as separate attachments. Supporting documents described below are number according to their Step number in the Level 1 Validation 10-step methodology. Starred documents should be considered <u>must-have for the QWLA to certify the audit</u>. Non-starred documents should be obtained if practical.

2. Documents for Audit Metrics
   - ★ 2.1 Water audit file (Excel) and basis of audit documentation available from all previous years.
   - 2.2 Examples of key documented results and data include customer meter accuracy testing results, unauthorized consumption investigations, customer billing system data mining analysis, or other activities that demonstrate enhanced control of apparent losses.
   - 2.3 Real loss levels can be judged as representative by documented results or data supporting leak detection, pressure management and/or water main rehabilitation/replacement activities that demonstrate enhanced leakage management and control of real losses.

3. Documents for Water Supplied
   - ★ 3.1 Monthly water supplied volume summary for the audit year, if possible broken-down by source, pressure zones or other major water supply configurations.
   - ★ 3.2 Recent finished water (production flowmeter) meter accuracy test results. Accuracy test documentation should include numeric results, test data and indication of test methodology (comparative testing vs. signal verification, duration, etc.) – i.e. a statement that the flowmeter "passed" or "failed" is not sufficient.
   - 3.3 Derivation of master meter & supply error adjustment inputs. This can include numeric adjustments tabulated during the audit year to account for known flowmeter inaccuracy, as well as adjustments to account for disruptions in tank storage balances and corrected gaps in the supply data trail.
   - 3.4 If the water distribution system configuration is complex, a schematic of the system can be submitted to show the locations of production flowmeter sites, major supply transmission pipelines, and other significant features of the water supply system.

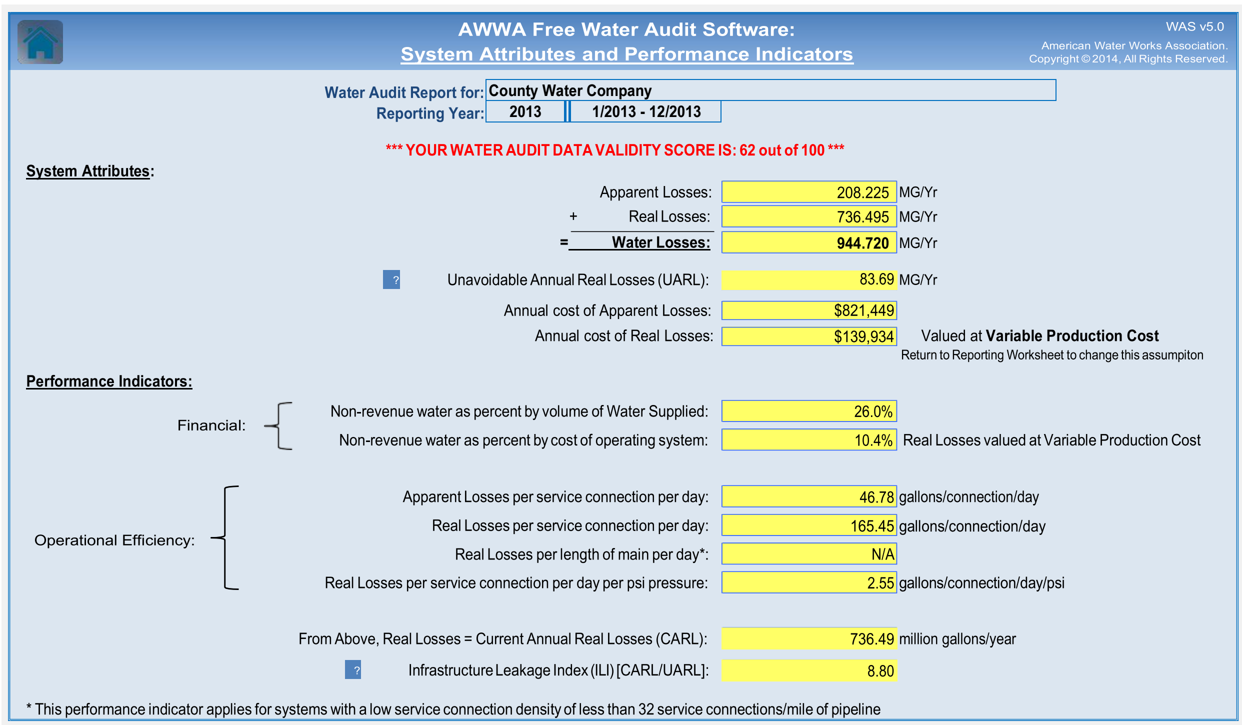
4. Documents for Authorized Consumption
   - ★ 4.1 For billed water consumption, provide volumes sold by rate code, by month. Include brief explanation of rate codes. Provide derivation of flat rate if the customer population is unmetered.
   - 4.2 For unbilled water consumption, provide any available summary of tracking data such as flushing and fire department usage estimates.

5. Documents for Apparent Loss
   - 5.1 Documented results and data from customer meter accuracy testing.
   - 5.2 Derivation of customer meter inaccuracy input.

6. Documents for System Data
   6.1 Derivation of the number of active and inactive customer service connections input.
   6.2 Any available recent pressure data from permanently installed or temporarily installed pressure loggers, or hydraulic model results.
   6.3 Derivation of the average operating pressure input.

7. Documents for Cost Data
   7.1 Accounting statements that determine the Total Cost of Operating the Water Supply System for the audit year.
   ★ 7.2 Customer retail rate schedule for the audit year.
   ★ 7.3 Derivation of customer retail unit cost input.
   ★ 7.4 Derivation of variable production cost input.

2. STEP 2 – Initial Screening of Audit Metrics – Checklist. Refer to the System Attributes and Performance Indicators worksheet of the AWWA Free Water Audit Software



AWWA Free Water Audit Software:
System Attributes and Performance Indicators

WAS v5.0
American Water Works Association.
Copyright © 2014, All Rights Reserved.

Water Audit Report for: County Water Company
Reporting Year: 2013 | 1/2013 - 12/2013

*** YOUR WATER AUDIT DATA VALIDITY SCORE IS: 62 out of 100 ***

System Attributes:

Apparent Losses:	208.225	MG/Yr
+ Real Losses:	736.495	MG/Yr
= Water Losses:	944.720	MG/Yr
? Unavoidable Annual Real Losses (UARL):	83.69	MG/Yr
Annual cost of Apparent Losses:	$821,449	
Annual cost of Real Losses:	$139,934	Valued at **Variable Production Cost** Return to Reporting Worksheet to change this assumpiton

Performance Indicators:

Financial:	Non-revenue water as percent by volume of Water Supplied:	26.0%	
	Non-revenue water as percent by cost of operating system:	10.4%	Real Losses valued at Variable Production Cost
Operational Efficiency:	Apparent Losses per service connection per day:	46.78	gallons/connection/day
	Real Losses per service connection per day:	165.45	gallons/connection/day
	Real Losses per length of main per day*:	N/A	
	Real Losses per service connection per day per psi pressure:	2.55	gallons/connection/day/psi
	From Above, Real Losses = Current Annual Real Losses (CARL):	736.49	million gallons/year
	? Infrastructure Leakage Index (ILI) [CARL/UARL]:	8.80	

* This performance indicator applies for systems with a low service connection density of less than 32 service connections/mile of pipeline

2.1 The System Attributes and Performance Indicators Worksheet of the WAS should be reviewed by the auditor before submitting the audit. Without reviewing and proofreading this worksheet, the auditor might overlook suspicious values which may result in the audit being returned for review before Level 1 Validation takes place. Upon submittal of the water audit, the auditor should provide supporting documentation for various activities particularly if any of their System Attributes or Performance Indicator values fall with extreme ranges of validated summary datasets. By not having good documentation available to support data inputs and gradings, the auditor risks extending the time needed to conduct the Level 1 Validation.

2.2 Be watchful for performance indicator values that appear to off by one or more orders of magnitude (i.e., 10, 100, or 1,000 times a number that you would expect). This can occur if the auditor misinterprets the units for the customer retail cost or misinterprets that the primary inputs of the water audit are in “million” gallons per “year” (the gallons units are used for most water audits submitted in the US). It may also occur simply because a number was not typed correctly into the water audit, and audit was not sufficiently proofread before submittal.

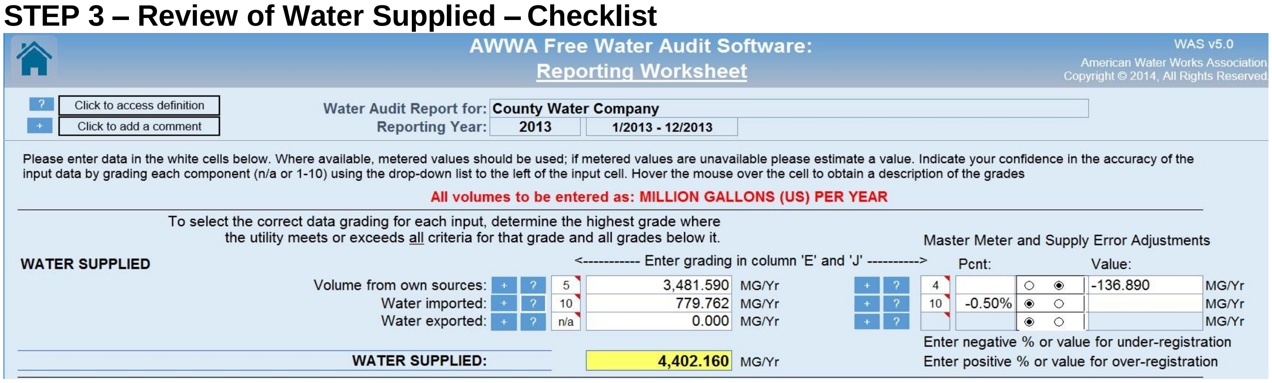
2.3 Is the volume of Water Losses and Non-revenue Water very low? Perhaps the Water Supplied Volume is under-stated, or the Billed Authorized Consumption and/or Apparent Losses are over-stated (watch out for double-counting of the Water Exported volume!).

2.4 Are the Apparent Losses Normalized Performance Indicator and the Customer Retail Cost very low, relative to data from validated datasets? Are the gradings for the three Apparent Loss components high (8 or above)? Utilities with low customer retail rates are less incentivized (monetarily) to control apparent losses. Review the activities in place to control apparent losses. Have the endeavors been successful because of a management motivation or another reason? If considerable apparent loss control activities have not been conducted, then low loss attributes and indicators may reflect data errors. Absent robust apparent loss controls, the grading of one or more apparent loss components may be too high. Perhaps the Water Supplied Volume is under-stated, making the water losses – and quantities for apparent losses – appear erroneously low.

2.5 Are the Real Losses performance indicators, including the ILI, and the Variable Production Cost all very low, relative to data from validated datasets? Utilities with low variable production costs are less incentivized (monetarily) to control real losses. Note the nature and extent of leakage management activities that are employed. For a utility to truly have low leakage performance indicators, their leakage management practices must be extensive and/or their water distribution system is very young and robustly designed and constructed. If extensive leakage management controls are not being implemented, perhaps their volume of apparent losses in the water audit is over-stated, making the calculation of real losses erroneously low.

2.6 The AWWA Compiler can be used to trend/chart any data point from multiple years of audits. This can be a helpful tool in Step 2 and subsequent steps. The AWWA Compiler is free download at: www.awwa.org/waterlosscontrol

3. STEP 3 – Review of Water Supplied – Checklist



3.1 For water utilities with multiple years of data, does the Water Supplied Volume deviate significantly from the volume reported in the previous year, or prior several years? (The AWWA Compiler Software can reliably display these trends.) If so, is there a reasonable explanation for this difference, or could it suggest an error in this data for the current year’s audit data?

3.2 Is the volume of Water Losses, Non-Revenue Water, or value of the Infrastructure Leakage Index (ILI) very low (ILI approaching or below 1.0)? Very low loss levels, particularly for utilities that do not have significant loss control interventions in place, might suggest that the Water Supplied Volume is under-stated.

VFOS, WI, WE

3.3 Note the number of water sources providing supply, and the type, size, and age of each finished water meters (flowmeter) on these sources.

VFOS, WI, WE

3.4 Note the flowmeter accuracy testing methods (if any) that are employed. Note if they include flowmeter accuracy verification in addition to secondary instrumentation calibration. Note frequency of these tests for each flowmeter, and the numeric results. Confirm supporting documentation and input derivation aligns with input values for master meter & supply error adjustments. A grade of 8 or higher requires both secondary instrumentation calibration <u>and</u> flowmeter accuracy verification.

MMSEA

3.5 Note how the flowmeter data is communicated from the field sites and channeled into a data repository. Does the utility use a SCADA system to provide this function? Is the data tabulated and reviewed on a regular and frequent basis? Does this occur daily, weekly, or monthly? Are corrections or adjustments implemented on a daily or weekly basis? Is the Water Supplied Volume determined on a daily basis by taking into account water storage tank/reservoir elevation changes and the balancing of flows across pressure zones and District Metered Areas, as appropriate? If data management does not include daily balancing of flows and tracking of tank levels, the highest grading that can be assigned for the MMSEA of Volume from Own Sources is a 3.

3.6 Confirm the assigned data grades align with the utility's practices and supporting documentation. For water audits with a Data Validity Score of 91 or more (Level V of the Water Loss Control Planning Guide), be very critical in the assessments of the data gradings for the six sub-components that lead to the calculation of the Water Supplied Volume.

•

4. STEP 4 – Review of Authorized Consumption – Checklist

AUTHORIZED CONSUMPTION

Billed metered:	+ ?	7	3,258.200	MG/Yr	
Billed unmetered:	+ ?	n/a	0.000	MG/Yr	
Unbilled metered:	+ ?	3	15.420	MG/Yr	
Unbilled unmetered:	+ ?	8	183.820	MG/Yr	Pcnt: ○ ◉ Value: 183.820 MG/Yr
AUTHORIZED CONSUMPTION:	?		**3,457.440**	MG/Yr	

Unbilled Unmetered volume entered is greater than the recommended default value

Click here: ? for help using option buttons below

Use buttons to select percentage of water supplied

•

4.1 For water utilities with multiple years of data, does the Authorized Consumption deviate significantly from the volume reported in the previous year, or prior several years? (The AWWA Compiler Software can reliably display these trends.) If so, is there a reasonable explanation for this difference, or could it suggest an error in this data for the current year's audit data?

BILLED METERED

4.2 Note percentage of customer population that is metered vs. billed on fixed (flat) basis. Note percent of estimated reads on average each billing cycle. Note average and range of customer meter ages. Note profile of meter read type (all manual, drive-by AMR, fixed network AMI, or indicate portions) and meter read frequency. Note if lag-time calculation is employed in the derivation of the Billed Metered Consumption input.

4.3 Note nature of customer meter testing policy – reactive (complaint driven) vs proactive (routine). Note frequency of customer meter testing – how many tested each year, and what is the basis for test: complaint or group selection (meters pulled for performance or replacement, random, other). Note differences in these practices between small customer meters and large customer meters. Verify documentation supports information noted.

4.4 Note policy for customer meter replacement – how many replaced each year, and what is the basis for replacement (upon failure only, age threshold, consumption threshold, test results, geography, other). Note differences in these practices between small customer meters and large customer meters.

BILLED METERED

4.5 Note nature, frequency and source of audits performed on the customer billing system (spot check by financial auditor, detailed data mining and analysis by staff or consultant, other).

4.6 Verify from supporting documentation that correct timeframe (12 months) has been utilized in the tally of consumption volumes. Verify by rate code summary volumes that non-potable volumes (sewer, raw, reuse, storm) have been excluded from the tally. Verify that summation of volumes by billed rate code matches total entered as Billed Metered Consumption, with no double counting of unbilled volumes. If a volume is shown in the Water Exported input, verify that this same volume has been excluded from the Billed Metered Consumption input.

BILLED UN-METERED

4.7 Note utility's policy indicating which customers are unmetered. Note percentage of accounts that are exempt from metering requirement. Note accounts included in this category for the utility. Note basis by which this input volume is derived.

UNBILLED METERED

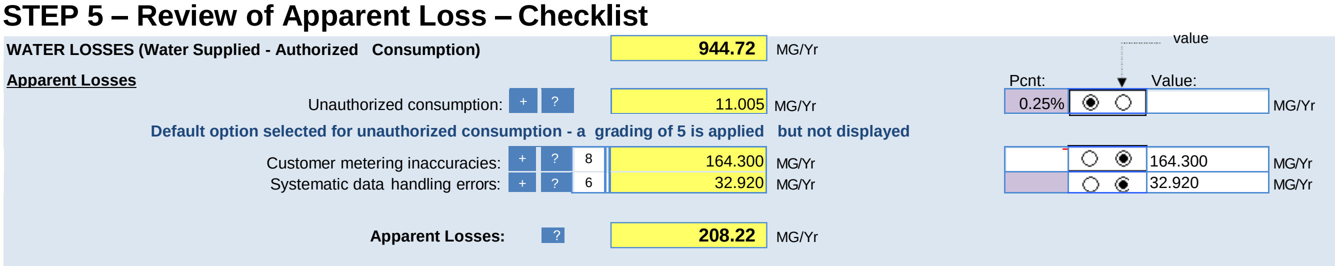
4.8 Note utility's policy indicating which customers are unbilled. Note accounts included in this category for the utility. Note basis by which this input volume is derived. Note if these unbilled meters are read and managed same or differently from billed meters. Verify that unbilled volumes are excluded from the Billed Metered Consumption input.

UNBILLED UN-METERED

4.9 If default value is utilized, note types of uses that are in this category for the utility. If the default value is utilized, and many unbilled uses such as flushing are metered and included in the Unbilled Metered Consumption input, consider adjusting to a volume below the default. If non-default input utilized, review supporting documentation for reasonableness of magnitude of estimates and basis for estimates (categorical estimation, event based formula approach, other). Verify that estimations of leakage volumes are excluded from this input. Be alert if a large emphasis is placed on unbilled, unmetered consumption, making it the majority component of NRW. For most utilities, this component is a very small portion of NRW.

4.10 For water utilities with multiple years of data, does the Unbilled Unmetered deviate significantly from the volume reported in the previous year, or prior several years? (The AWWA Compiler Software can reliably display these trends.) If so, is there a reasonable explanation for this difference, or could it suggest an error in this data for the current year's audit data?

5. STEP 5 – Review of Apparent Loss – Checklist



•

UNAUTH CONSUMP

5.1 Note the utility policy on theft documentation. Note the qualitative frequency (low, mid, high) of discovery of theft occurrences. Compare to default percentage as basis for adjustment if warranted.

5.2 Note the utility policy on theft enforcement and penalties.

CUSTOMER METERING INACC

5.3 Note nature of customer meter testing policy – can copy from item 4.3. Note more detail on testing methodology – internal vs external, bench vs field, flow ranges utilized per AWWA M6 Manual. Confirm how multiple test flow ranges were reconciled to a single test result – arithmetic vs weighted average, and weightings used. Review derivation of Customer Meter Inaccuracy input, verify alignment with supporting meter test data. Watch for disconnect between detailed test data and generalized input. Note if procedures have been reviewed by a third party knowledgeable in M36 methodology.

5.4 Note nature of customer meter replacement policy – can copy from item 4.4. Note more detail on relationship between meter testing and meter replacement to verify if one dictates the other.

SDHE

5.5 Note policy on estimating consumption – scenarios in which this occurs, and for how long. Note policy to activate a new customer/meter and deactivate an old customer/meter. Note policy for billing adjustments and how this might impact integrity of archived consumption volumes.

6. STEP 6 – Review of System Data – Checklist

SYSTEM DATA

Length of mains:	+ ?	4	256.3	miles
Number of active AND inactive service connections:	+ ?	4	12,196	
Service connection density:	?		48	conn./mile main
Are customer meters typically located at the curbstop or property line?			No	(length of service line, beyond the property boundary, that is the responsibilityof the utility)
Average length of customer service line:	+ ?	5	18.0	ft
Average operating pressure:	+ ?	3	65.0	psi

-

6.1 For water utilities with multiple years of data, do each of the four (4) System Data inputs deviate significantly from those reported in the previous year, or prior several years? (The AWWA Compiler Software can reliably display these trends.) If so, is there a reasonable explanation for this difference, or could it suggest an error in this data for the current year's audit data?

LENGTH OF MAINS

6.2 Note average and range of age and material composition of the pipe network. Note policy for updating & maintaining mapping database as mains are commissioned or decommissioned. Note coverage (full, partial) and nature (paper, GIS, asset management database, other) of mapping database. Note policy for field validation of mapped assets and verification between GIS and asset management databases.

6.3 Verify hydrant leads are included in tabulation of length of mains.

6.4 Verify if derivation of the Length of Mains input is from mapping database or an approximation.

Nc

6.5 Note policy for new account activations. Note policy for updating & maintaining accounts database as new connections are commissioned or decommissioned. Note policy for field validation of service connections and verification between GIS and customer account databases.

6.6 Note policy for service connections moving to inactive status. Verify if input derivation is from customer information database or an approximation. Verify whether input includes active and inactive connections.

AVG Lp

6.7 Note policy for utility/customer separation of service line responsibility and placement of meter. Verify input of "0" utilized if customer meters are placed at property line.

6.8 If all meters are not placed at property line, verify input derivation as a weighted calculation between portion of meters at property line (with Lp = 0) and portion of meters on premise (with average Lp >0).

AVG PRESSURE

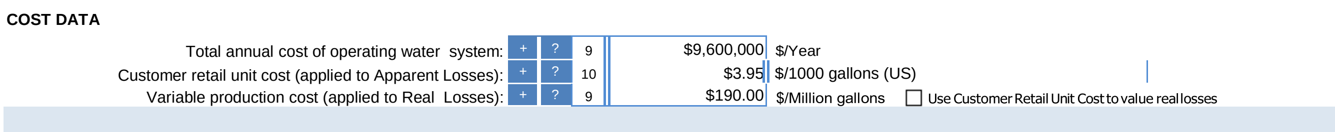
6.9 Note configuration of pressure zones in the network, with estimated range and average pressure for each zone. Note estimated mileage and service connections by pressure zone, if available.

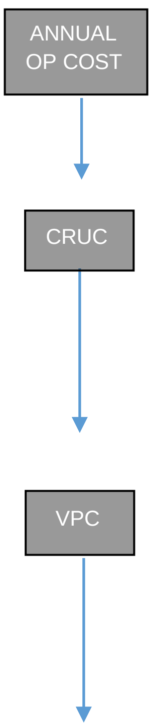
6.10 Note nature of pressure data (static readings, temporal pressure logs, continual telemetry logs, other).

6.11 Review average pressure supporting documentation. Note extent of field generated pressure data (plants, booster stations & tanks only, critical and average point monitoring, portion of hydrants, other). Note utilization of hydraulic model and policy for model calibration.

6.12 Verify if derivation of average pressure input is from pressure database or an approximation. Make sure that the background data feeding the average pressure calculation is from the current audit year, and not dated data from a prior year.

7. STEP 7 – Review of Cost Data – Checklist





7.1 For water utilities with multiple years of data, do any of the below costs/cost rates deviate significantly from those reported in the previous year, or prior several years? (The AWWA Compiler Software can reliably display these trends.) If so, is there a reasonable explanation for this difference, or could it suggest an error in the cost data? Remember: it is much more common for costs to *increase* from year-to-year. A decrease in any cost relative to the prior year – while plausible – should be understood and documented. Any inordinately large increases should also be explained.

7.2 Note frequency (annual, periodic, other) and source (internal, external CPA, other) of auditing of water accounting system. Note alignment of time period for costs reported and audit period.

7.3 Verify that the Total Annual Cost of Operating the Water System does not include sewer or other non-potable water costs. If combined budget, verify the method for separation of water costs. Verify whether debt service for water projects and/or depreciation for water assets are included.

7.4 Review supporting documentation. Note nature (uniform, class-based, tier-based) of customer retail rate structure. Note if derivation of input is an estimation, a selected rate, or a weighted average from all billing rates.

7.5 If derivation of input is from total volume sold divided by total water revenue, verify that base charges are excluded from total water revenue. Verify if any non-potable volumes (i.e. sewer) which are charged on the basis of water meter readings are included in the input derivation. Note if procedures are reviewed by third party knowledgeable in M36 methodology.

7.6 Verify that units are correct.

7.7 Review supporting documentation. Verify if derivation of input includes primary costs (power, chemicals, purchased water if applicable) only versus secondary costs (water treatment residuals, liability, pump depreciation, impending expansion of supply if applicable, other). Note the frequency (annual, periodic, other) and source (internal, third party CPA, third party knowledgeable in the M36 methodology, other) for auditing of these primary and secondary costs.

7.8 Verify derivation of input uses produced / purchased volumes that are corrected for error adjustments (i.e. MMSEA applied).

8. STEP 8 – Final Screening of Audit Metrics – Checklist

This step repeats some of the review conducted in Step 2. However, by now gross errors or incomplete data should not be an issue with the water audit. The system attribributes and performance indicators can now be reviewed knowing that the input data has been validated and obvious data input errors should not be a factor.

8.1 For utilities that have multiple years of water audit data, place the validated water audit into the Compiler Software and again review the year-to-year trend of data and performance indicators. Do any significant variations in values from year-to-year appear? If so, can the utility provide an explanation for the variance? Could a subtle data input error still remain?

8.2 Does the volume of Water Losses and Non-revenue Water remain very low? Is there still a possibility that the Water Supplied Volume is under-stated, or the Billed Authorized Consumption and/or Apparent Losses are over-stated? If any of these components/sub-components are of low validity, they might be contributing to the unusually low level of losses. It is also prudent to reconfirm that the Water Exported volume has not been double-counted by including it also in Billed Metered Consumption.

8.3 Do the Apparent Losses Normalized (gal/service conn/day) value and the Customer Retail Cost remain very low, relative to data from validated datasets? Are the gradings for the three Apparent Loss components validated to be at a high level (8 or above)? Utilities with low customer retail rates are less incentivized (monetarily) to control apparent losses. Conduct a further review of the activities in place to control apparent losses. If considerable apparent loss control activities have not been conducted, then low loss attributes and indicators may reflect data errors. Consider recommending cost-effective bottom-up apparent loss control activities that the utility might undertake in the upcoming year. Such activity might return uncaptured revenue and provide more robust data to better represent the apparent loss levels and performance indicators in the water audit.

8.4 Do any of the Real Losses performance indicators, and the Variable Production Cost remain very low, relative to data from validated datasets? Utilities with low variable production costs are less incentivized (monetarily) to control real losses. Reconfirm the nature and extent of leakage management activities that are employed. For a utility to truly have a very low ILI, their leakage

AWWA Free Water Audit Software:
System Attributes and Performance Indicators

WAS v5.0
American Water Works Association.
Copyright © 2014, All Rights Reserved.

Water Audit Report for:
Reporting Year:

***** YOUR WATER AUDIT DATA VALIDITY SCORE IS: 63 out of 100 *****

System Attributes:

Apparent Losses:	206.627	MG/Yr
+ Real Losses:	98.763	MG/Yr
= **Water Losses:**	**305.390**	MG/Yr
? Unavoidable Annual Real Losses (UARL):	83.70	MG/Yr
Annual cost of Apparent Losses:	$816,177	
Annual cost of Real Losses:	$18,765	Valued at **Variable Production Cost** Return to Reporting Worksheet to change this assumption

Performance Indicators:

Non-revenue water as percent by volume of Water Supplied:	13.4%	
Non-revenue water as percent by cost of operating system:	9.1%	Real Losses valued at Variable Production Cost
Apparent Losses per service connection per day:	46.42	gallons/connection/day
Real Losses per service connection per day:	22.19	gallons/connection/day
Real Losses per length of main per day*:	N/A	
Real Losses per service connection per day per psi pressure:	0.34	gallons/connection/day/psi
From Above, Real Losses = Current Annual Real Losses (CARL):	98.76	million gallons/year
? Infrastructure Leakage Index (ILI) [CARL/UARL]:	1.18	

* This performance indicator applies for systems with a low service connection density of less than 32 service connections/mile of pipeline

management practices must be extensive and/or their water distribution system is very young and robustly designed and constructed. If extensive leakage management controls are not being implemented, perhaps their volume of apparent losses in the water audit is over-stated, making the calculation of real losses erroneously low. Consider recommending cost-effective bottom-up real loss control activities that the utility might undertake in the upcoming year. Such activity might provide more robust data to better represent the real loss levels and performance indicators in the water audit, while also producing additional, documented leakage reductions.

8.5 As a final part of Step 8 – the QWLA should document in the General Comments regarding the water loss metrics, and how they align with the utility's extent of water loss management. If a discrepancy is observed, such as a utility having a high levels of loss despite an aggressive loss management program - or low levels of loss in the absence of an aggressive loss management program - the QWLA should review Steps 3 – 7 to identify is anything was missed in the review. If the root cause of the discrepancy is cannot be found through supporting documentation and utility staff interviews, the QWLA should include in the General Comments a description of the likely cause(s) and guidance on where deeper investigations (i.e. Level 2 validation data mining or Level 3 validation field testing) may be warranted.

General Comment:	QWLA: Walter P. Loss, wploss@mwu.org, QWLA #0117. Audit prepared by Frank Smith, fsmith@mwu.org. Initial screening of metrics shows metrics to be off by several orders of magnitude. Corrected volume units to MG/year. Metrics in line with validated datasets. Final screening: ILI is at 1.2, suggesting very low levels of leakage, which is not consistent with the age/condition of the network and the absence of an active leak detection program in the utility. Likely cause of this discrepancy is understating of production volumes due to master meter error or data gaps in the SCADA archives. Field testing of production meters and data chain between primary/secondary/tertiary devices is recommended to verify production volumes. Discrepancy could be also a result of overstating of consumption volumes, a detailed analysis of the consumption data queried from billing system for use in the water loss audit may be needed.

9. STEP 9 – Assemble Supporting Documents and Validation Form – Checklist

9.1 The QWLA should reconfirm all checklist answers and any other pertinent information gained in the review, and proof-read all of the validation documentation now included in each cell of the Comments worksheet of the audit software. It can be helpful to the validation process for future years' water audits if system description information (additional system data, test procedures, billing protocols, etc.) are highlighted in this documentation. Much of this information does not change notably from year-to-year. It can be very helpful to next year's validation reviewer if this information stands out, and the reviewer does not need to question the utility on these practices repeatedly. Some of this information may also be included as separate attachments.

9.2 Be certain that the reasons for data grading selections are clearly documented. Discuss with the auditor the means to elevate certain gradings by improved activities in the upcoming audit year.

10. STEP 10 – Complete water loss audit certification statement for EPD submittal

10.1 The QWLA should assemble the water audit file with basis of audit documentation (Excel document including Reporting Worksheet and Comments tabs), and prepare it for submittal to EPD. If the validation reviewer has opted to record the basis of audit documentation on a comparable format, such as a separate Excel or MS Word file, that should be attached with the submittal to EPD. Regarding all supporting documentation (as described in Step 1), these documents should be excluded from the submittal and kept on file by the QWLA and the auditor, to be made available if requested by EPD.

10.2 The QWLA should complete the water loss audit certification statement and provide this to the utility for inclusion in their EPD submittal.

3.9 QWLA Certification Form

Water Loss Audit Information:

Utility Name: ____________________________

PWS ID #: ____________________________

Water Loss Audit Prepared by (Primary Contact): ____________________________

Water Loss Audit Year Reviewed: ____________________________

Certification Statement:

I hereby certify that:

1. I HAVE CONDUCTED A VALIDATION REVIEW OF THE ABOVE REFERENCED WATER LOSS AUDIT AND THE RESULTS MEET THE REQUIREMENTS IN THE GEORGIA WATER SYSTEM AUDITS AND WATER LOSS CONTROL MANUAL AND THE AMERICAN WATER WORKS ASSOCIATION METHODOLOGY FOR WATER LOSS AUDITING.
2. THE BASIS OF AUDIT DOCUMENTATION FOR THE ABOVE REFERENCED WATER LOSS AUDIT IS INCLUDED EITHER IN THE COMMENTS TAB OF THE AUDIT FILE OR ATTACHED IN COMPARABLE FORMAT.

Qualified Water Loss Auditor Information:

First & Last Name (print): ____________________________

QWLA Registration Number: ____________________________

QWLA Signature: ____________________________

Certification Date: ____________________________

SECTION 4 – Planning a Water Loss Control Program

4.1 Starting Your Water Loss Control Program – Understanding *Apparent* vs. *Real* Losses

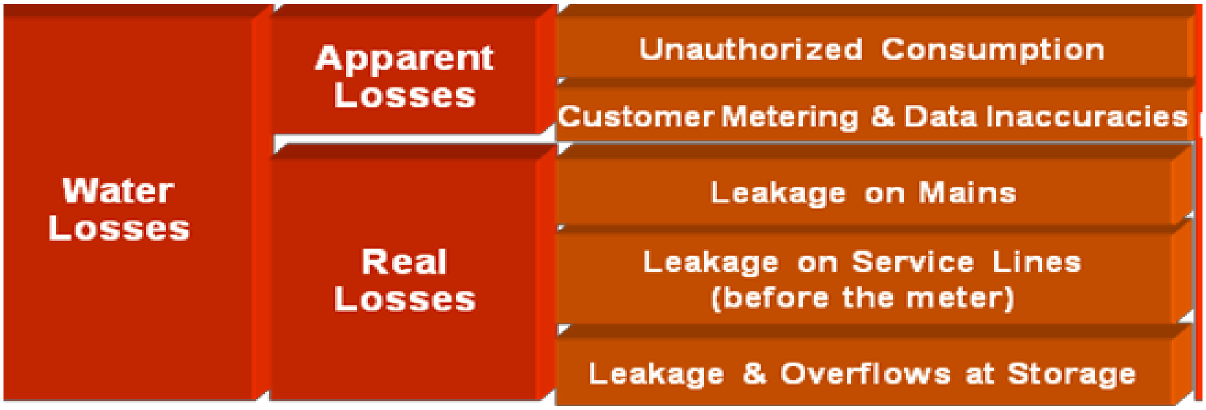
According to the AWWA Water Loss Control Manual, there are two broad types of water losses that occur in drinking water utilities, which are defined as:

Apparent losses are the non-physical losses that occur in utility operations due to customer meter inaccuracies, systematic data handling errors in customer billing systems and unauthorized consumption. In other words, this is water that is consumed but is not properly measured, accounted for or paid for. These losses cost utilities revenue and distort data on customer consumption patterns.

Real losses are the physical losses of water from the distribution system, including leakage and storage overflows. These losses inflate the water utility's production costs and stress water resources since they represent water that is extracted and treated, yet never reaches beneficial use.

NOTE: *Water Supplied* in the AWWA *Free Water Audit Software*© is derived from *Volume from Own Sources* and/or *Water Imported* minus *Water Exported*. It is critical that this input be as accurate as possible when using the audit to develop a water loss control program. It is recommended in the AWWA Water Loss Control Manual that production meters be tested, at least annually, as well as calibrated. Production meter testing is different from calibration. Testing is physical flow verification using an independent measuring device. Calibration is an electronic adjustment to ensure the measurement from the meter is being converted and communicated accurately. A meter over registering would result in inflated water loss where an under registering meter may mask a significant amount of loss in a system. Either of these inaccuracies would result in an ineffective water loss control program. More information on this can be found in AWWA *M36 Manual.*

Figure 1: IWA/AWWA Water Audit Method and Apparent vs. Real Losses



4.2 Water Loss Control Program: Apparent Losses Component

The general categories with basic descriptions of water losses are listed below. More specific sources of data within each category are provided in **Table 1**. The sources listed in **Table 1** are not all-inclusive and are provided only as a guide on potential sources of data, which will be needed to complete your informal audit.

- **Unauthorized Consumption**

  This category includes theft of water such as illegal connections, unauthorized use of fire hydrants, meter tampering, etc.

  - Water providers should use the default number of 0.25 percent provided in the software unless they can compile accurate water theft data. Supporting data should be saved in a new tab in the companion workbook for future reference.

  - Ways to minimize unauthorized consumption include, but are not limited to, reassessing policy and regulations for permitted water supply services, public education on theft, cooperation with other entities to report violations, better trained meter readers, theft bounties or rewards, more secure hydrant locks, etc.

Customer Metering Inaccuracies

These are inaccuracies that result from the improper sizing or maintenance of meters.

- Solutions to minimize inaccuracies are to operate a proper meter testing and replacement program, utilize a meter sizing program rather than having meters chosen by cost, periodic review of the usage compared to meter sizing to determine if a different size or type of meter is more appropriate, etc.
- Water providers are encouraged to refer to AWWA*'s Manual M6* (Water Meters, Selection, Installation, Testing and Maintenance) or AWWA *Manual M22* (Sizing Water Service Lines and Meters) for more information.

Systematic Data Handling Errors

These are errors occurring between the point of data input as meter readings and the data output or archived in customer billing systems.

- Errors include billing system entry errors, account adjustments, invalid zero consumption readings, meter rollover, meter change out, etc.
- Solutions to minimize errors include enhanced QA/QC on data entry, switching from manual to automated meter readings (AMR), enhanced software, and detailed comparisons of water production to water billed over time.

NOTE: Use care when considering *estimated bills*. If estimated consumption is reduced based on better available data, these negative adjustments may constitute an apparent loss. All adjustments should be reviewed closely to determine the appropriate categorization as billed metered, billed unmetered, unbilled metered or apparent loss.

Table 1: Potential Causes of Apparent Losses

Unauthorized Consumption	**Customer Metering Inaccuracies**	**Systematic Data Handling Errors**	
Entities that are NOT AUTHORIZED to use water	**Field Measurement / Calibration Issues**	**Internal Data Handling /Transfer Errors**	**Data Analysis / Billing Program Errors**
Unauthorized fire hydrant usage	Calibration errors	Manual adjustments to usage (hand)	Improper or erroneous multipliers
Connection to unmetered fire line	Meter installation errors	Adjustments that replace original data	Manual adjustments to bills but not volumes (changed entry)
Customer installed bypass (residential or commercial)	Open/leaking bypass valve	Long term "no reads"	Usage adjustments based on short-term estimates
Unauthorized connections to other systems (border areas)	Under or oversized meters or improper type of meter	Improperly recorded meter data from crossed meters	Adjustments due to known leakages
Fire Sprinkler system testing (private or industrial)	Tampering with meter reading equipment	Estimated readings from malfunction or exchange of meters (excludes temporary inclement weather issues)	Adjustments that do not leave original data in place and change it to a new reading
Internal connection to fire line by entity or staff	Improper repair of meter reading equipment	Procedural/data entry errors for change outs and new meters	Adjustments to prior year volumes (entry update)
Meter Vandalism (internal or external)	Untimely meter installations	Improper programming of AMR equipment	Long-term "no reads" are not flagged
Fountains/ water features (unmetered but **authorized**)	Untimely final reads	Non-billed status. Meter is in place and not being read (rental, vacancy, etc.)	Computer / Billing software issues (malfunctions, programming errors, etc.)
Special Events (unmetered but **authorized**)	Buried/"lost" meters	Customer meters left unread due to account setup problems	Inconsistent policy interpretations by staff
Infrastructure Cleaning (streets, bus stops, etc.) (unmetered but **authorized**)	Equipment failure	Using a combined large/small meter calibration error	Customer lost in system
Line disinfection by contractors(unmetered but **authorized**)		Customer *lost* in system with incorrect contact info.	Improper programming of AMR equipment
Repair efforts by others with unreported system damage (unmetered but **authorized**)		AMR equipment failure	Discretionary decisions or political "adjustments"

Revenue Recovery from Water Loss Control Activities

Water loss control programs can have significant financial benefits if developed and implemented properly. First, apparent loss reduction will directly increase income to the water system, due to the nature of apparent losses being valued at the retail water rate. Activities to reduce unauthorized consumption can include GIS mapping of water meters to analyze customers that may not be metered, installation of detector checks or meters on customer fire lines to prevent cross connection, fire hydrant locks, better enforcement of unauthorized fire hydrant use, and a door-to-door customer census, to name a few.

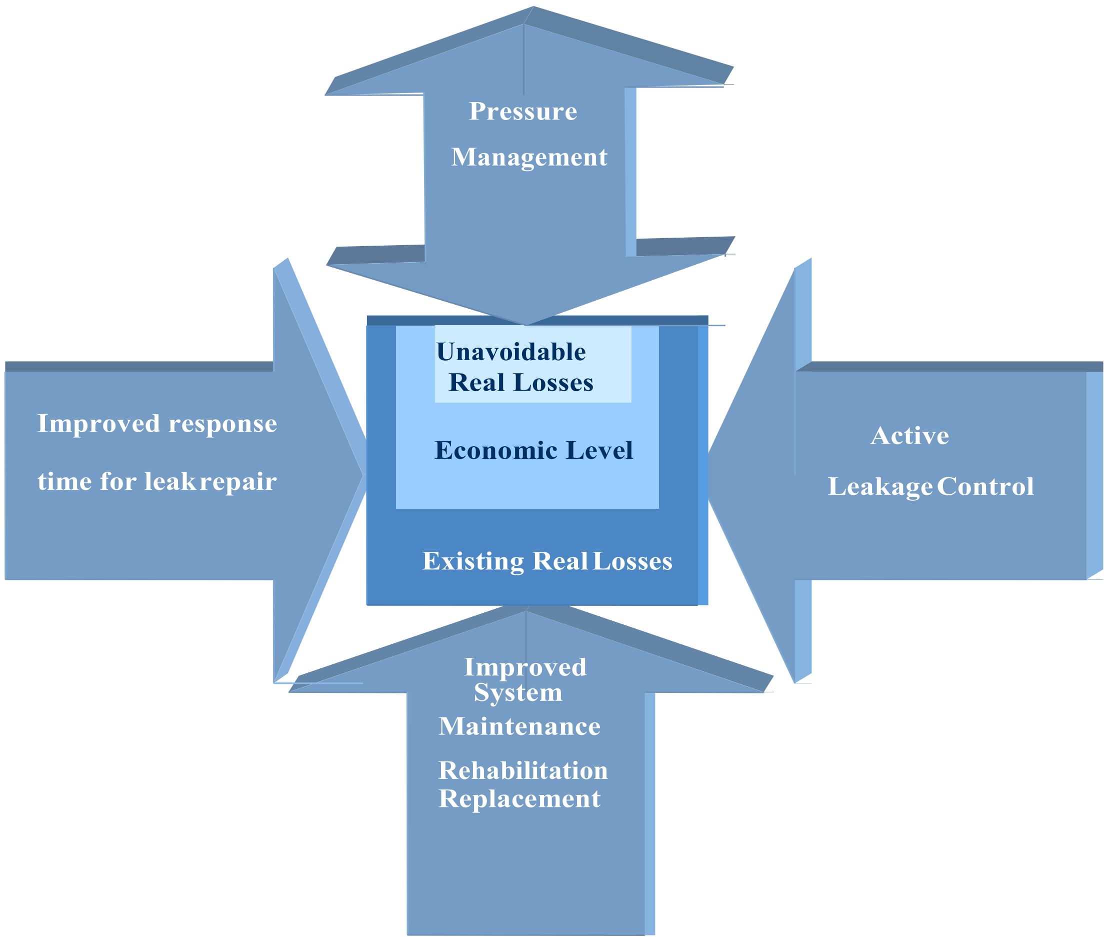
The other component of apparent loss is the business process of accurately metering, reporting, billing and collecting water usage fees. This process can be quite extensive, and may include installation of appropriate size meters on all authorized users, a proactive customer meter calibration and replacement program, and consideration for Automated Meter Reading (AMR) systems or Advanced Metering Infrastructure (AMI), customer service practices (everything from account setup to billing adjustments), billing frequency, bill format, billing rates, and collection practices. An extensive business practices audit of these can be performed to determine which will provide the most improvement and financial benefit.

While revenue recovery is more directly related to reduction of apparent losses, an effective real loss reduction program can also contribute to the water system's financial improvement. Real loss reduction not only reduces day-to-day operational costs by reducing the amount of water needed to produce and distribute (usually through pumping), it can also reduce overall system demand and defer costly capital improvements in production and distribution infrastructure or water resources expansion. Direct savings from real loss reduction is calculated using the production (and pumping) cost of water, but the financial benefits extend beyond this direct calculation. Activities can include pressure management to reduce background leakage, improved response time for leak/break repair, an active leak detection and management program, and proactive asset maintenance and rehabilitation.

4.3 Water Loss Control Program: Real Loss Component

Proactive leakage management is designed to control the *real* portion of water loss, which includes leaks on mains and service lines and overflows at storage facilities. **Figure 2** illustrates the four components of controlling real losses. As each component receives more or less attention, the losses will increase or decrease from each category.

Figure 2: The Four-Pillar Approach to the Control of Real Losses



Source: AWWA Manual M36, *Water Audits and Loss Control Programs* (2014).

Active Leakage Control and Timely Leak Repair Programs

As noted previously, physical losses in the distribution system are referred to as real losses. Real losses, which consist of a recoverable component and an unavoidable component, include leakage on transmission and distribution mains, leakage and overflows at the system's storage tanks, and leakage on service connections up to the customer meter.

Cost-effective management of real losses in a water distribution system can be achieved by examining the potential causes, evaluating potential activities for minimizing these causes, and implementing those activities deemed most appropriate. The desired objective is to achieve the economic level of real losses as appropriate for each water distribution system.

In 2002, AWWA conducted a survey of 96 water systems, each serving more than 100,000 people. The results of this survey indicated that the most common leakage management techniques employed by these systems included the following leak detection technologies:

- Leak noise correlation (43 percent)
- Ground microphones (36 percent)
- Listening sticks (27 percent)
- Leak Noise loggers (22 percent)

Pressure Management

The average system pressure is a very important parameter in calculating the unavoidable annual real losses (UARL), and system pressure is by far the greatest influencing factor for leakage in a distribution system. All systems are unique and the pressure will vary based on the average geographic size of the system, the elevation changes, the demand patterns, and other local considerations. An extensive body of work exists in the field of pressure management and its part of a broader real loss reduction and control program. For more detailed guidance on this topic, refer to the AWWA *M36 Manual*.

Implementing Pilot Programs for Leakage Management

Subsequent recommendations in this category cover investment in additional leak detection resources and strategies such as in-house crews, equipment, contractors, and operational changes including active pressure management. When evaluating the feasibility of each option and selecting the best tools for the system, it is necessary to determine the potential payback associated with each option.

The use of leak noise loggers as a method for reducing the run time of unreported leakage is becoming more common. These devices are programmed to listen for leak signatures during low demand periods, typically during overnight hours when vehicular traffic is generally at a minimum. They record leak noise data for later analysis of potential leak occurrences. Leak noise loggers complement the conventional leak survey and detection methods while utilizing a fraction of the manpower required using conventional leak detection equipment. These devices, which are typically placed in valve boxes on top of valve operators at intervals of approximately 1,000 feet, allow the operator to pinpoint the precise location of the leak.

Leak noise loggers may also be used in conjunction within District Metered Areas (DMA) although this might represent a duplicate level of active leakage control. In creating a DMA, a portion of the distribution system is temporarily or permanently re-configured to measure all inflows at one or two entry points to an isolated area on a continuous basis. The inflows would then be compared to the sum of customer meters within the isolated area to determine potential leakage. It is important to note that care must be taken when establishing the DMAs to ensure that acceptable water quality and adequate domestic service and fire protection capability are maintained.

The frequency of leak detection system surveys vary within the industry, with some large utilities targeting a cycle time of one year. For each system, a more readily attainable goal such as three to five years is an appropriate target. As the system’s data collection and evaluation process improves to allow a more accurate assessment of real versus apparent losses, the applicability of a targeted leak detection cycle can be revisited and the leak survey frequency adjusted accordingly.

In determining resource requirements, the system must also consider the amount of effort required to address emergency and work order responses, and how this effort may be reduced through increased proactive leak detection activity.

It is important to note that an increased investment in proactive leak detection will elicit an initially increased number of unreported leak work orders generated for response by the system’s leak repair crews. In order to effectively manage real water loss, the system will need to determine an appropriate level of investment in repair crews and equipment to maintain its desired response goal. The objectives for this process should include:

1. Quantifying the backlog of leak repair work to be done;
2. Identifying a reasonable time frame in which to eliminate those existing work orders;
3. Establishing baseline estimates of work orders generated on a monthly basis; and,

4. Setting performance metrics that would allow the system to address the estimated quantity of work orders and eliminate the existing backlog in a timely manner.

Storage Tank Overflows and Leakage

As noted previously, leakage and overflows from storage tanks increase a water system's avoidable real losses. The proper design, operation, maintenance and inspection of storage tanks are important components of a water loss control program. Recommendations for controlling real loses from storage include:

- Storage tanks should be designed and operated to prevent overfilling (ex. correct overflow elevation, level control sensors, altitude valve);
- Level-control sensors and altitude valves should be inspected regularly (weekly if possible) and maintained to ensure proper operation;
- Tanks should be inspected for leaks, overflows, vandalism, and visible damage by water system personnel frequently (weekly if possible) and after all natural disasters and extreme weather events; and,
- A professional tank company should perform a comprehensive inspection of each storage tank every 3 to 5 years.

The information provided in **Table 2** summarizes the financial implications of water losses from a sample large water provider. In the table, apparent losses are valued at the entity's customer retail unit cost of water (1,043 MG apparent loss water volume ×$2.34 per thousand gallons for the example), while real losses are valued at the water provider's variable production cost (3,718 MG × $425 per MG for the example). This approach reflects the fact that apparent losses represent lost revenue, while real losses represent inefficiency and must be offset through production of additional treated water or additional purchased water.

Table 2: Financial Performance Indicators for Large Water Provider Case Study

Parameter	**Result**
Annual Cost of Apparent Loss	$2,441,000
Annual Cost of Real Loss	$1,580,000
Total Annual Cost of Water Loss	$4,021,000
Total System Operating Cost	$30,000,000
NRW (Percent of System Operating Cost)	13.4%

The significance of the data in **Table 2** is that it provides a basis against which the costs of improved water loss management can be evaluated to determine a scale of appropriate investment. As noted previously, real losses represent operating inefficiency because of the increased volume of treated water that must be produced or purchased to offset water lost through events such as leaks, pipe breaks and tank overflows. However, practical considerations dictate that real water losses cannot be completely eliminated and a portion of real losses are unavoidable.

4.4 Water Loss Control Program: Demonstration of Progress

The 2015 Georgia *Rules For Public Water Systems to Improve Water Supply Efficiency* (Chapter 391-3-33) sets forth the requirement that a water system be able to document progress towards improved water supply efficiency in its system when it applies for a water withdrawal permit or an increase in permitted water service connections. The demonstration of progress may be evaluated by EPD as part of the review of a permit application to 1) renew, or 2) modify an existing water withdrawal permit to increase the permitted water supply, or 3) increase the number of permitted service connections. The *Rules* specify four areas through which progress may be documented. These are data validity score improvement (to the extent practicable for a given system), developing and implementing a water loss control program, improvement in the performance measures of Operational Basic Real Losses (Op24) and Operational Basic Apparent Losses (Op23) once a reliable level of validity score has been reached, and demonstration that the system has achieved and is maintaining its Economic Level of Leakage.

Note: It is recommended that the water system create a **separate spreadsheet** to use for tracking the volume of water saved in the various component categories (and the various methods used) and to relate to revenue recovery or cost reduction as appropriate.

Economic Level of Leakage

The economic level of leakage (ELL) can be broadly defined as the level of leakage at which any further investment in leakage reduction would incur costs in excess of the benefits derived from the savings. This includes both the cost of producing the water as well as the avoided cost of replacing the water. It should also be noted that economic evaluations performed on real loss reduction activities should only be performed when several years of water audits have been conducted and data validity has been improved to reflect the reliability of the audit to make the use of performance indicators meaningful. ELL is used for leakage reduction target setting and setting the frequency of leak survey investigations.

Much more information and a more formal software model for determining a system's level of economic water loss can be found in the free Water Research Foundation publication "Real Loss Component Analysis: A Tool for Economic Water Loss Control" (Web Report #4372a). Access this report through the Water Loss Control Committee page on the AWWA website.

Infrastructure Leakage Index (ILI)

The ILI calculated by the AWWA *Free Water Audit Software*© is an important benchmark for water system planning. It can also be used as a target-setting mechanism, but only for water systems just starting their water auditing process. Each water system should determine their own target ILI, based on operational, financial and water resources considerations. The target-setting assessment is unique to each system, so no system should simply copy a leak reduction target established for another system.

Remember that the Infrastructure Leakage Index is a system's current annual real losses (CARL) divided by the system's Unavoidable Annual Real Losses (UARL). The UARL is that low level of loss within a system that will remain even if all of the current best technology were successfully implemented within a system. If a water system's CARL equals its UARL, the ILI will be 1.0. In other words, all the real losses that are theoretically feasible to eliminate using current best technology will have been eliminated at an ILI of 1.0. All that remains are the unavoidable real losses.

The AWWA *M36 Manual* provides guidelines for using the ILI as a preliminary target-setting tool within a specific water provider. The determination of a system specific ILI should take into account water resource availability, operational considerations, and financial goals of the water provider. **Table 4** summarizes ILI target setting guidance from AWWA.

Once a water system has moved past the initial auditing and has a basic leakage management program in effect, real loss reduction can then be tracked using several indicators such as real losses/service connection/day or real losses/mile-of-mains/day/psi of pressure. These indicators allow for quantifiable financial spending and recovery goals. Over time, the water system can track their progress and success using these additional performance indicators from the water audit.

Table 4: Infrastructure Leakage Index Target-Setting Guidance *(From* AWWA *M36 Manual)*

Note: This guidance is presented in lieu of performing a full economic analysis of leakage control options.

Note: Utilization of ILI or other performance indicators if the data validity scores less than 50 and audit has not been *validated* is premature and unreliable.

Target ILI Range	Water Resources Considerations	Financial Considerations	Operational Considerations
1.0 – 3.0	Available resources are greatly limited and are very difficult and/or environmentally unsound to develop	Water resources are costly to develop or purchase	Operating with leakage above this level would require expansion of infrastructure or new water resources
3.0 – 5.0	Resources are sufficient if good demand management measures are in place	Water resources can be developed or purchased at reasonable expense	Existing supply infrastructure is sufficient as long as leakage is controlled
5.0 – 8.0	Water resources are plentiful, reliable and easily extracted	Cost to purchase or obtain/treat water is low, as are rates charged to customers	Superior reliability, capacity and integrity of infrastructure make the system immune to supply shortages
Greater than 8.0	Although operational and financial considerations may allow a long-term ILI greater than 8.0, such a level is not an effective utilization of water as a resource. Setting a target level greater than 8.0 – other than as an incremental goal to a smaller long-term target – is discouraged.		
Less than 1.0	If the calculated ILI value is 1.0 or less, two possibilities exist: a) world class low leakage levels are being maintained, or b) a portion of the data may be flawed.		

Regardless of the calculated ILI, each water provider must establish individual goals to work toward that apply strictly to the system. Numerous combinations of improvements are listed in the various tables describing different parameters and what it takes to achieve the next level of *effectiveness*. The ILI can act as a barometer for an individual system, giving a quick indicator of changes within the audit data. Given a constant UARL, increases or decreases in real losses will result in the ILI fluctuating higher or lower. The UARL might also change, as in the case of changing system-wide water pressure, miles of pipe added to the distribution system, and more or fewer service connections. As your system data becomes more refined, it is quite possible that your system ILI will increase. It is better to have a higher ILI within better quality data than to have a low ILI that is calculated from less accurate data. Ultimately, more accurate data allows a system to properly target water loss control measures that give the best return on investment. In other words, it helps you spend limited public financial resources wisely.

4.5 Financing Sources Matrix

Funding Option	Funding Option Characteristics	Contact information (website)
Federal/state loan or grant programs		
Georgia Environmental Finance Authority (GEFA)	• Low-interest loans and some grant funds • Quick approvals • Apply year-round • Interest rate reductions for water conservation projects	www.gefa.org
Georgia Department of Community Affairs (DCA)	• Community Development Block Grant Program • Grant funds with a $500,000 maximum per project • Very competitive program • Annual funding cycle; applications due April 1 of each year	www.dca.state.ga.us/communities/cdbg
United State Department of Agriculture (USDA)	• Low-interest loans and grants • 40-year financing terms • Apply year-round	www.rurdev.usda.gov/GAHome.html
Environmental Protection Agency (EPA)	• Competitive grant programs may exist for small water systems • EPA is supportive of local water loss initiatives	water.epa.gov/drink
Private Funding		
Local Banks	• Borrowing remains at the local community • Local banks often desire to provide funding for local projects	Contact your local bank
Bond Market	• A referendum is typically required to issue a municipal bond • The bond market can provide a variety of repayment options	www.bloomberg.com/news/bonds
Private Banks	• Large regional or national banks will provide funds for a variety of infrastructure activities	Contact your regional bank
Performance Contracting	• Cost of borrowing can be paid from water loss savings • Private performance contracting companies will fund projects through a guarantee of cost savings	www.energyservicescoalition.org
Self-funding		
SPLOST tax	• A referendum is typically required to create a SPLOST tax • Funds can be used for a variety of activities	N/A
General Fund	• Does not require borrowing funds from third-party • All tax payers pay for the project, though all tax payers may not be customers of the water system	N/A
Water Enterprise Fund	• Operating funds typically exist for water loss projects	N/A

	• Funds can be used for a variety of activities • Customers of the water system directly pay for the project	

SECTION 5 – Supplemental Information

5.1 Definitions

Note: The following are standardized definitions (normal font) and performance indicators (in *italics*) used in the IWA/AWWA water audit methodology. Some definitions may vary slightly between water providers based on political decisions and internal billing policies.

- ***Apparent Losses***: Unauthorized consumption, all types of customer metering inaccuracies, and systematic data handling errors in customer billing operations.
- **Authorized Consumption**: The annual volume of metered and unmetered water consumed by customers, the water supplier, and others who are authorized to do so. This does not include water sold to other utilities, which is considered water exported.
- **Average Length of Customer Service Line**: Distance beyond the customer property line that the utility is responsible for maintaining, typically zero in Georgia.
- **Average Operating Pressure**: The average system pressure is a very important parameter in calculating the unavoidable annual real losses (UARL). All systems are unique and the pressure will vary based on the extent of the system, the elevation changes, the demand patterns, and other local considerations.
- **Billed Metered Water:** This includes retail water that is metered and billed for domestic, commercial, industrial or government customers. This number does not typically include wholesale water sent to neighboring water systems.
- **Billed Unmetered Water:** This includes water that is not metered but is billed and may include customers who are not metered, but charged only a fixed fee or other method, or customers with estimated usage.
- **Cost of Operating Water System—Total Annual:** These costs include those for operations, maintenance and any annually incurred costs for long-term upkeep of the drinking water supply and distribution system. It should include the costs of day-to-day upkeep and long-term financing such as repayment of debt for infrastructure expansion or improvement. Typical costs include employee salaries and benefits, materials, equipment, insurance, fees, administrative costs and all other costs that exist to sustain

the drinking water supply. Depending upon water utility accounting procedures or regulatory agency requirements, it may be appropriate to include depreciation in the total of this cost. Costs to operate wastewater and other non-potable water operations should not be included.

- **Customer Metering Inaccuracies:** Inaccuracies result from wear, improper sizing or maintenance of meters.

- **Customer Retail Unit Cost**: This is the overall charge that customers pay for water service per unit of water and is applied to apparent losses.

- **Data Validity Score***:* This is a composite rating of a utility's confidence and accuracy of data entered into the AWWA *Free Water Audit Software*©. A lower score means the data is less reliable and the utility should focus on improving its data inputs so the software can accurately assess the system water losses. **Note**: A "good" data validity score is one that is considered *reflective*, be it high, low or in-between.

- **Economic Level of Leakage (ELL):** ELL can be broadly defined as the level of leakage at which any further investment in leakage reduction would incur costs in excess of the benefits derived from the savings. This includes both the cost of producing the water as well as the avoided cost of replacing the water. It should also be noted that economic evaluations performed on real loss reduction activities should only be performed when several years of water audits have been conducted and data validity has been improved to reflect the reliability of the audit to make the use of performance indicators meaningful. For more detailed guidance on this topic, refer to the AWWA M36 Manual.

- **Infrastructure Leakage Index (ILI)**: ILI is the ratio of current annual real losses (CARL) to unavoidable annual real losses (UARL). For most utilities the ILI can be an effective performance indicator for operational management of real losses. When the data validity score is high, an ILI close to "one" indicates the utility's real losses are close to the unavoidable annual real loss level and therefore further reductions in real water losses might not be cost effective. A utility's ILI will fluctuate annually depending on the data collection for each year and therefore should be considered in conjunction with a utility's data validity score and ILI from previous years.

It is important to remember that the ILI is only one measure of system efficiency. One must look at anomalies such as large single occurrence leaks and any other outlying factors when assessing all water losses.

- **Length of Mains**: Total length of water distribution pipelines, including fire hydrant leads. This length does not include customer service connection lines.

- **Non-revenue Water**: The sum of unbilled authorized consumption, apparent losses and real losses. The term *non-revenue water* should be used instead of the imprecise term *unaccounted-for water*. It is recognized that **some** of this component water of non-revenue water is authorized consumption (unbilled).

- **Non-revenue Water Percent by Cost**: The value of non-revenue water as a percentage of the annual cost of running the system. This is a good financial indicator that quantifies the financial impact to the water utility from losses when broken down into authorized and unauthorized components. This indicator could be used when issuing bonds, setting water rates, or other financial functions.

- **Non-revenue Water Percent by Volume**: This indicator has value as a very basic, high-level financial indicator; however, it is misleading to employ this indicator as a measure of operational efficiency. This indicator should not be used for performance tracking, system comparisons, or benchmarking.

- **Number of Active and Inactive Service Connections**: The number of customer service connections, extending from the water main to supply water to a customer. Please note that this includes the actual number of distinct piping connections, including fire connections, whether active or inactive. This may differ substantially from the number of customers (or number of accounts).

- **Operational Basic Apparent Losses (Op23)**: A basic performance indicator that assesses apparent losses in gal/service connection/day. Normalizing the apparent losses calculated through the water audit provides the water utility with a mechanism to monitor these losses as system conditions change and as water loss control measures are implemented.

- **Operational Basic Real Losses (Op24)**: A basic performance indicator that assesses Real Losses in gal/service connection/day or gal/miles of main/day depending on the utility's connection density. This indicator is useful for target setting, and has limited use for comparisons between systems.

- **VFOS Master Meter and Supply Error Adjustment**: An estimate or measure of the degree of inaccuracy that exists in the master (production) meters measuring the annual Volume from Own Sources, and any error in the data trail that exists to collect, store and report the summary production data.

- **Real Losses**: The annual volumes lost through all types of leaks and breaks in water mains and service connections, up to the point of customer metering. Real losses all include overflows from treated water storage tanks or reservoirs.

- **Revenue Water**: The components of the system input volume that are billed and produce revenue.

- **Systematic Data Handling Errors**: Apparent losses caused by accounting omissions, errant computer programming, gaps in policy, procedure, and permitting/activation of new billing accounts; and any type of data handling lapse that results in under-stated customer water consumption in summary billing reports. Utilities typically measure water consumption registered by water meters at the customer premises.

- **Unavoidable Annual Real Losses (UARL)**: These losses are reported in gallons, based on miles of mains, number of service connections, total length of customer service connection pipe from curb stop to customer meter, and average system pressure. The UARL is a theoretical reference value representing the technical low limit of leakage that would exist in a distribution system even if all of today's best leakage control technology could be successfully applied in that system. The UARL is not a performance indicator but is used as the denominator in calculating the Infrastructure Leakage Index (ILI). No system can achieve *zero water loss* because water distribution systems are not perfectly sealed. The UARL is a system-specific calculation that varies among systems as the miles of pipe increases, system pressure changes, connections are added/lost, and other system changes are made.

    - **Special Note**: **The UARL calculation has not yet been proven fully effective for very small or very low pressure water systems**.

If: (Lm x 32) + Nc < 3,000 (where Lm = length of mains, Nc = number of customer service connections)

Or: P < 35 psi, where P = average system pressure

Then the calculated UARL may **NOT** be reliable. The AWWA *Free Water Audit Software*© will not calculate a UARL value for systems that meet these conditions.

- **Unbilled Metered Water**: This includes water that is metered, but not billed, such as water provided free of charge for municipal purposes (unbilled public facilities, unbilled public irrigation, etc.).

- **Unbilled Unmetered Water**: This includes unmetered water that is unbilled for authorized uses such as; firefighting, flushing of mains or sewers, street cleaning, etc.

- **Unauthorized Consumption**: This includes theft of water such as illegal connections, unauthorized use of fire hydrants, meter tampering, etc.

- **Validation**: The process of validation confirms the integrity of the component water consumption and loss values in the water audit. The validation of all performance indicators and values used in the determination of these indicators is of utmost importance. Data of low validity will lead to inaccurate performance indicator values and poor guidance for the water utility. No matter how sound the auditing process, poor data gives an inaccurate picture of the water system and its performance.

- **Variable Production Cost**: The current unit cost to treat and distribute water to the system. This includes the variable costs associated with the production of water (including treatment and distribution pumping costs) and wholesale water purchases.

- **Volume from "Own Sources"**: The amount of finished water leaving the water treatment plant, entering the distribution network and recorded by the production master meter(s).

- **Water Exported**: Water sold to a neighboring utility or regional water authority.

- **Water Imported**: Water purchased from a neighboring utility or regional water authority.

- **Water Losses**: The difference between System Input Volume and Authorized Consumption, consisting of Apparent Losses plus Real Losses.
- **Water Supplied**: The total volume of treated water that leaves the water treatment plant or other treated water sources and enters the distribution system.
- **WE Master Meter and Supply Error Adjustment:** The adjustments made to the export meter(s) recorded volumes based on meter flow verification that accounts for errors in measurement, calibration, data gaps from communicating interruptions or other data archival issues.
- **WI Master Meter and Supply Error Adjustment:** The adjustments made to the import meter(s) recorded volumes based on meter flow verification that accounts for errors in measurement, calibration, data gaps from communicating interruptions or other data archival issues.

5.2 Sources of Data for Authorized Consumption

Sources of Data for Authorized Consumption			
Billed Metered	**Billed Unmetered**	**Unbilled Metered**	**Unbilled Unmetered**
Any location with a meter and receiving a bill	**Any location receiving a bill and does not have a meter**	**Any metered account that does not have a bill**	**Any consumer that does not have a meter or bill and is AUTHORIZED to use the water**
Industrial customers	Unmetered systems or areas	Institutional customers	Firefighting and other fire dept. uses (testing and training)
Commercial customers	Flat rates	Government irrigation meters	Line flushing (automatic and manual)
Residential customers	County/City construction projects including free water		
Institutional customers		Line disinfection	Line disinfection
Irrigation meters		Vactors (pipeline cleaning, street cleaning, dust control, etc.)	Vactors (pipeline cleaning, street cleaning, dust control, etc.)
Fire hydrant meters			
Private fire lines	Private fire lines		
Volume sales to tanks/trailers within service area using a meter	Volume sales to tanks/trailers within service area using container volume or other calculation		Repair efforts by others (private utility services)
Water Authority / Government	Water Authority / Government	Water Authority / Government	Water Authority / Government
Schools	Schools	Schools	Schools
Religious/charity institutions	Religious/charity institutions	Religious/charity institutions	Religious/charity institutions
Special events	Special event (set fee for service)	Special events	Special events
Infrastructure cleaning (streets, bus stops, etc.)	Infrastructure cleaning (streets, bus stops, etc.)	Infrastructure cleaning (streets, bus stops, etc.)	Infrastructure cleaning (streets, bus stops, etc.)
Pools (filling and maintenance)	Pools (filling and maintenance)	Pools (filling and maintenance)	Pools (filling and maintenance)
Water fountains/features	Water fountains/features	Water fountains/features	Water fountains/features
Special contract sales for cash or in-kind services	Special contract sales for cash or in-kind services	Special contract sales for cash or in-kind services	Special contract sales for cash or in-kind services

Notes:

1. Several water uses may apply to several categories based on the system.
2. This list is not all inclusive, but rather a guide for collecting system data.

5.3 Sources of Data for Apparent Losses

Sources of Data for Apparent Losses			
Unauthorized Consumption	**Customer Metering Inaccuracies**	**Systematic Data Handling Errors**	
Entities that are NOT AUTHORIZED to use water	**Field Measurement / Calibration Issues**	**Internal Data Handling /Transfer Errors**	**Data Analysis / Billing Program Errors**
Unauthorized fire hydrant usage	Calibration errors	Manual adjustments to usage (hand)	Improper or erroneous multipliers
Connection to unmetered fire line	Meter installation errors	Adjustments that replace original data	Manual adjustments to bills but not volumes (changed entry)
Customer installed bypass (residential or commercial)	Open/leaking bypass valve	Long term "no reads"	Usage adjustments based on short term estimates
Unauthorized connections to other systems (border areas)	Under or oversized meters or improper type of meter	Improperly recorded meter data from crossed meters	Adjustments due to known leakages
Fire sprinkler system testing (private)	Improper repair of meter reading equipment	Estimated readings from malfunction or exchange of meters (excludes temporary inclement weather issues)	Adjustments that do not leave original data in place and change it to a new reading
Internal connection to fire line by entity staff	Untimely meter installations	Procedural/data entry errors for change outs and new meters	Adjustments to prior year volumes (entry update)
Meter or reading equipment vandalism (internal or external)	Buried/"lost" meters	Improper programming of AMR equipment	Long term "no reads" are not flagged
Water fountains/features	Meter failure	Non-billed status where meter is in place and not being read (rental, vacancy, abandoned, sale property)	Computer / Billing software issues (malfunctions, programming errors, etc.)
Special events		Customer meters left unread due to account setup problems	Inconsistent policy interpretations by staff
Pools and operations of		Untimely final reads	Customer lost in system
Infrastructure cleaning (streets, bus stops, etc.)		Using a combined large/small meter calibration error	Improper programming of AMR equipment
Line disinfection (contractors)		Customer lost in system	Political "adjustments"
Repair efforts by others with unreported system damage		AMR equipment failure	

SECTION 6 - References and Resources

- AWWA *Free Water Audit Software*©
  http://www.awwa.org/resources-tools/water-knowledge/water-loss-control.aspx

- AWWA M36: *Water Audits and Loss Control Programs* (published 2014, 4th Edition).
  www.awwa.org

- Georgia AWWA Water Loss Control Committee
  www.gawp.org

- AWWA Water Loss Control Committee
  http://www.awwa.org/resources-tools/water-knowledge/water-loss-control.aspx

- Georgia Water Stewardship Act
  http://www.gaepd.org/Files_PDF/Water/sb370.pdf

- Georgia Water Conservation Plan
  http://conservewatergeorgia.net

- Alliance for Water Efficiency – Tracking Tool
  http://www.allianceforwaterefficiency.org/Tracking-Tool.aspx

- AWWA M-22: *Sizing Water Service Lines and Meters.*
  www.awwa.org

- AWWA M-6: *Water Meters – Selection, Installation, Testing, and Maintenance.*
  www.awwa.org

- *Real Loss Component Analysis: A Tool for Economic Water Loss Control*, Water Research Foundation, Project 4372a, 2014.